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PAPERS AND PROCEEDINGS OF THE ANNUAL MEETING

OF THE AMERICAN MOSQUITO CONTROL ASSOCIATION HELD JOINTLY WITH THE ANNUAL MEETING OF THE FLORIDA ANTI-MOSQUITO ASSOCIATION DAYTONA BEACH, APRIL 12-17, 1953

AERIAL APPLICATION OF GRANULAR INSECTICIDES IN SOUTHEASTERN PENNSYLVANIA

RUSSEL W. GIES

Principal Sanitary Engineer, Pennsylvania Department of Health, Media, Pa.

The use of granular insecticides applied from an airplane in two different types of areas was tried out in 1952 in Pennsylvania.

TYPE ONE: On about 600 acres of fresh water marshes along Darby Creek between southwest Philadelphia and Chester, Pennsylvania, in Tinicum Township. This large block of marshland had been a heavy mosquito breeder because of sewage pollution. The high vegetation which grew up on the marshes after July 1, consisting of reeds and tall grass, cattails, etc., made it impractical to use liquid sprays which were effective earlier than July 1, but which were caught and held by the rapid growth of vegetation so that only about 15% to 30% of the liquid insecticides heretofore used would get down into the water to act as a larvicide.

The first application of granular insecticide was made in early July and was followed at intervals of about three to four weeks in August and September, a total of three applications being made. The material used for the first of these three applications was either 15% or 10% Rothane or DDD furnished by Rohm and Haas Company of Bristol, Pennsylvania, and incorporated in the tobacco dust furnished by the Tobacco By-Products and Chemical Corporation of Richmond, Virginia. The preparation of the dust was carried out by the latter company. The second and third applications were carried out with 10% DDT incorporated in the tobacco dust by the same companies.

The change was made largely because of technical difficulties in manufacturing under excessively hot summer conditions. Application was made by the LeHava Air Services of Philadelphia, Pennsylvania, with an experienced pilot in a specially modified biplane.

RESULTS: The results proved conclusively that virtually 100% of the granular material used would penetrate through practically any kind of tall vegetation to give effective control as a larvicide at the rate of application of approximately one pound per acre of DDT, using 7 to 10 pounds of dust into which DDT had been incorporated, remaining effective up to four weeks under normal conditions. There did not seem to be any serious fish killing with the use of either DDD or DDT in the quantities used, up to one pound per acre.

Although the cost would probably be somewhat higher than the use of liquid sprays, from an acreage basis, the fact that practically 100% of the material reached the water surface under the vegetation would more than compensate for the difference in cost.

It is felt that quantities of from one-quarter to one-half pound per acre of DDT in this dust would be as effective as one pound per acre of the liquid spray.

As part of this material was furnished

free for experimental purposes by the companies mentioned above, the exact costs are not available.

TYPE TWO: A long narrow strip of the abandoned Schuylkill Canal approximately 100 feet wide, including banks of the canal, and 35 miles long, owned by the Commonwealth of Pennsylvania, between a point west of Norristown and extending through Phoenixville, Pottstown, Reading and as far as Hamburg, Pennsylvania, was dusted four times with the same materials as mentioned above and with the same general results.

IMPROVING AERIAL APPLICATIONS [1]

F. E. WHITEHEAD

Ark. Agr. Exp. Sta.

The use of pelletized or granular insecticides offers possibilities of improving aerial applications for the control of mosquito larvae from the standpoint of both effectiveness and economy.

A. Effectiveness: 1. Wherever mosquito producing waters have vegetative cover above them much better penetration and consequently better control may be obtained with pellet-borne insecticides.

Economy: 1. The small amount of drift makes possible the application of such insecticides from much greater heights and hence with greater safety than when applied as dusts or sprays. Such qualities make practical the use of light planes costing but a small fraction of the price of large planes. Their operating expenses are also much lower. In Arkansas the total operating expenses have been but one-fifth to one-quarter the cost of the larger planes.

When two pounds per acre are applied and where scattered fields are to be treated, a light plane in 4 to 5 hours will cover approximately twice as much territory as the larger planes in one hour, thus reducing by one-half the cost of application.

2. If there is any movement of the water, strips of the insecticide in granular bentonite will do as well as complete coverage. Twenty-foot to 30-foot strips applied 67 feet apart in rice fields that were in the process of being flooded gave excellent control.

There is also some evidence that stripping is effective in stagnant water.

3. Work now under way at the Arkansas Experiment Station indicates that less expensive and perhaps better methods of preparing such insecticides will soon be available.

4. Let's get away from the idea that any thing under 10 acres should be treated with ground equipment. If the area to be treated can be found from the air, a light plane can go there, do the treating, and return in approximately the time required to get the equipment there in a light truck.

5. Because of their non-drifting qualities granular insecticides may be successfully applied during periods of greater air movement than dusts or sprays. As a result, the application of such insecticides can be continued more hours per day. This enables operators to be less likely to get behind with their work and makes more efficient use of the time of the pilot and air plane.

[1] Journal Series Paper 1086, Univ. of Arkansas. Published with the approval of the director of the Arkansas Agricultural Experiment Station.

A PROMISING NEW OIL FOR MOSQUITO CONTROL

ARTHUR H. BRONSON
Richfield Oil Corporation

In Bulletin VC-1 dated September 1951, of the State of California Department of Health, entitled "Mosquito Abatement in California," it was said that "With the advent of the new organic insecticides, oil, as a larvicide, has been relegated to a place of decreasing importance. It has been further limited in that, as a result of advancements of petroleum technology, the improvement of oils for uses other than mosquito control has effected the removal of certain toxic fractions."

With that statement in mind and the knowledge that the chlorinated hydrocarbons were losing their effectiveness through the development of resistance, the challenge became clear to us at Richfield. A screening program was instituted of all finished products heretofore used in the field and of all intermediate sidestreams, tank bottoms, and other possible fractions that could be made available in commercial quantities. This screening resulted in the isolation of one very promising oil; an intermediate in one of the refining cycles.

Chromatographic analysis of this oil showed it to consist of 50% non-aromatic hydrocarbons, 46% aromatic hydrocarbons, and 4% residue. The 46% aromatics present are divided into 22% monocyclic and 24% polycyclic aromatics. Typical boiling range is from 370 deg. F. to 626 deg. F., sulfur content approximately 1.5%, and specific gravity of the oil is .89. After the laboratory screening, .5% of a suitable surface tension reducing agent was added to the product which was then taken into the field for large scale tests. In cooperation with the Orange County Mosquito Abatement District, Richfield Larvicide was applied by John Shanafelt, Jr. at a rate of two gallons per acre. This dosage resulted in a kill of 99 plus % of *Culex stigmatosoma,* larvae and pupae. On 5-acre duck ponds with more than 50% emergent weed growth averaging two feet in height, six gallons per acre were applied by air. This application resulted in a 99 plus % kill of *Culex tarsalis.*

After preliminary testing, Ted Raley of the Consolidated Mosquito Abatement District, Selma, California (in the first commercial scale application of Richfield Larvicide), used approximately 2,500 gallons of this product with reported excellent results.

Mr. C. M. Gjullin, in his test work at Corvallis, with 10% distillation cuts of Richfield Larvicide, showed no significant differences in toxicity of the ten boiling range fractions with respect to each other or the product as a whole, which confirmed our own findings. Using cuts separated into hydrocarbon types by silica gel adsorption, greatest toxicity was effected by those cuts in the dicyclic aromatic range. This has led us to believe that the inherent toxicity of the product is more closely related to hydrocarbon type rather than boiling range. Richfield Larvicide will, because of the aromatics present, fluoresce under ultra-violet light. The entrance of this oil through the siphon tube, thence the trachea, can readily be traced with a black light in a darkened room. It was possible and most interesting to note the concentration of the material in the thoracic region.

We, at Richfield, feel that the day has passed when those charged with mosquito control must use, where oil is required, the regular petroleum products ordinarily found in commerce for larval control. It is our belief that mosquito control is of such importance as to warrant the distribution of a petroleum product specifically developed for that use.

RESEARCH BY THE U. S. ARMY CORPS OF ENGINEERS ON INSECT AND RODENT CONTROL OPERATIONAL METHODS AND EQUIPMENT

AUSTIN W. MORRILL, JR. AND GEORGE J. BURTON

Eng. Res. and Dev. Labs., Ft. Belvoir, Va.

Since the revolution in insecticidal application methods which commenced with the advent of DDT, a great deal of research and field experimentation have been done by many civilian and governmental agencies in the attempt to develop new equipment for the new needs. It may, therefore, seem somewhat supererogatory for the military to set up additional research to study the matter. Military requirements, however, while concerned with the same end result, which is to say destruction of insects, are quite different from the civilian needs for this purpose. To be militarily useful, equipment must be far more than a good tool with which to kill the insects.

Ruggedness of the equipment is a primary military characteristic, because the most efficient machine in the world, if it is not able to withstand severe abuse, will fail in its military mission. After completion of engineering tests, field test models are procured and shipped to selected using organizations for service testing. Deficiencies in the equipment reported from service tests are evaluated, and necessary corrections are made in the final specifications and drawings. A final report, together with specifications and drawings, is then transmitted by the Engineer Research and Development Laboratories to higher Headquarters, recommending adoption, when applicable, of the equipment for troop use.

In October 1951, the Engineer Research and Development Laboratories at Ft. Belvoir, Va., established an Insect and Rodent Control Section, with the responsibility of doing research on insect and rodent control operational methods and equipment. Under outlines suggested by the Army Committee for Insect and Rodent Control, projects were initiated and approved by the Research and Development Board which included a 2-gallon, cylindrical, compression, pack-type sprayer, a fog generator, a mist blower, a hydraulic sprayer, and general research on existing operational methods and equipment, or means of modifying these, which might be of use to the Armed Forces.

In formulating our ideas as to the specific forms each piece of equipment should take, an extensive canvass is made of persons engaged in similar projects elsewhere in universities and in state and federal laboratories and field projects. The consensus is then analyzed and compared with the opinions which have been expressed, often with some vigor, by armed forces units in combat areas, in Communications Zones and other overseas areas, and in Preventive Medicine survey and control units in the United States. From these various opinions, pilot models are prepared and given use tests at Ft. Belvoir and in certain field areas such as Ft. Churchill, Canada, Orlando, Florida, etc. The tests are designed to ascertain volume and rate of output, particle size range, ease of operation, and suitability to military use. Tests of extremes of heat, cold, shock, and exposure to corrosive materials, are made at this time.

Following these engineering tests, field test models are prepared and sent out to Preventive Medicine units of all the armed services for use in routine operations. During these operations, equipment is subjected to all the usual hazards of military use, but is not given abnormally abusive treatment. The opinions of the test operators are solicited by questionnaire, and the answers are tabulated and the matter also discussed at length by letter, or, wherever

possible, in person. A final report is then written, drawings prepared of the improved and final model, and military specifications are drawn up for use in future procurement.

This somewhat complex process is designed to assure the maximum in proper design and in adaptation to the needs of the ultimate user. There has not been time, as yet, to make radical innovations or modifications of types of equipment in ordinary use. However, final drawings and military specifications have been prepared within the past year for a new 2-gallon, compression, pack-type sprayer.

This sprayer is cylindrical and weighs eleven pounds. The tank is fabricated of stainless steel because both plastic and ceramic coatings were found to separate from the steel under certain not-unusual conditions, and zinc-coated steel corrodes badly during shipment overseas even with only the condensate from the atmosphere within the tank. Many parts of the new model are formed of hardened aluminum to reduce weight. The filler opening is 2⅞ inches in diameter, making it easy to fill and empty the tank, and the screw-on type cap used in previous Army models has been retained to avoid use of an O-ring type of gasket which loses its effectiveness if any swelling occurs. A capillary tube within the wand, a small ball-spring valve in the nozzle strainer, and an improved and more positive-action cut-off in the trigger release provide virtual elimination of after-drip. A complete set of spare parts, which includes all gaskets, nozzles, and strainers, is sent with each sprayer.

Prior to acceptance by the government, an inspection of sample units selected at random is made to ascertain that each sprayer when sent out is airtight to a pressure of 120 lbs., and that all parts function and all gaskets are properly resistant to insecticides. Sturdy construction combined with careful inspection, training of users in care and maintenance of the sprayer and supplying them with spare units of the most critical or most fragile parts, has enabled the Armed Forces to use the present models of this sprayer for from 3 to 5 years in remote overseas areas.

The cost of the finished sprayer is not much greater than that of stirrup pumps and lightweight commercial models. For this reason, it is felt that sturdy construction is the most economical in the long run. Further research is expected to extend the usefulness of the units so that their cost will be even less than the approximate $6.00 now figured as the annual pro ratum of the purchase price over a period of 3 years.

In the same way, experimentation now being conducted is expected to supply simple, compact, rugged, effective (though perhaps not showy) equipment at a substantially reduced cost, for field use by the Armed Forces at home and overseas.

IT IS NOT TOO SOON TO BEGIN PLANNING FOR THE MEETINGS IN ATLANTIC CITY, NEW JERSEY, ON MARCH 8, 9, 10, 11, 12, 1954. An AMCA meeting with the New Jersey group is always an outstanding event for anyone concerned with mosquitoes. Secretary Ted Raley has already alerted the members to provide for budgeting expenses for the meetings. The Editor of *Mosquito News* would add: Keep your eyes open and your notebooks handy for items, short or long, worthy of reporting at the meetings.

Mosquito News sometimes runs preponderantly to technical articles, and the Editor here takes occasion to point out again that this is because that type of article predominates among those received for publication.

The taxonomists, chemists, physiologists, and toxicologists need no urging to report their work because its very nature implies the recording and interpreting of data in writing. Laboratory workers who realize that their photomicrographic or histological

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THE COMMITTEE ON VECTOR CONTROL OF THE AMERICAN PUBLIC HEALTH ASSOCIATION

G. H. BRADLEY

U. S. Public Health Service
Department of Health, Education and Welfare, Atlanta, Georgia

Public health has been one of the principal beneficiaries of the phenomenal advances in the control of insects resulting from the use of the marvelous new materials and methods developed during World War II. It follows quite naturally, therefore, that the American Public Health Association should show a considerable interest in this field. In 1952, this interest was reflected in the appointment of a formal committee within the Engineering Section of the Association whose purpose it is "to study the status of vector control activities in the United States; to analyze administrative and technical problems and practices in this field, and to prepare reports and recommendations on these subjects. Because of the diversity of vector control activities and the inherent interdependence with other health activities, it would seem that in future years joint studies and reports with other committees of the Association might be indicated."

The members of the Committee represent a broad range of interests and activities. They are:

W. E. Gilbertson—Chairman of the Committee, Chief, Division of Civilian Health Requirements, U. S. Public Health Service, Washington, D. C.

G. H. Bradley—Chief Entomologic Consultant, Bureau of State Services, U. S. Public Health Service, Atlanta, Georgia.

H. L. Fellton—Consulting Sanitary Engineer, Atlanta, Georgia.

F. E. Gartrell—Chief, Malaria Control Branch, Division of Health and Safety, Tennessee Valley Authority, Chattanooga, Tennessee.

J. M. Henderson—Sanitary Engineer Consultant, U. S. Public Health Service, Savannah, Georgia.

J. A. Mulrennan—Director, Division of Entomology, Bureau of Sanitary Engineering, Florida State Board of Health, Jacksonville, Florida.

T. A. Olson—Associate Professor of Sanitary Engineering and Public Health, University of Minnesota, St. Paul, Minnesota.

R. F. Peters—Chief, Bureau of Vector Control, California State Department of Public Health, Berkeley, California.

F. H. Stutz—Director, Dade County Anti-Mosquito District, Miami Florida.

Six of these committeemen also are members of the American Mosquito Control Association, a circumstance which should foster close working relationships between the two Associations.

For its initial activity and to provide a basis for further study and planning, the Committee gathered readily available data and prepared a report on "Vector Control Activities in the United States." This report was presented at the Meetings of the Association in Cleveland, Ohio, last October. It is not my purpose to discuss the report in detail; since it will be published in the Year Book of the American Public Health Association in May of this year and thus will be readily available to those who are interested. A few extracts from the report, however, which include references to mosquito activities, might be appropriate at this time.

The foreword to the report points out that during the past twenty-five years the growth of interest in vector control on the part of state and local health agencies has been steady, if not spectacular; that this growth has been shared by a diversity of other public agencies as well as by pest control operators; and that health agencies should recognize the need for a broader base of operations and should assume a greater degree of leadership if they would avoid excessive splitting up of responsibility in the vector control field. Broad

programs for the prevention of the viral encephalitides, Rocky Mountain spotted fever, gnat-borne conjunctivitis, and enteric infections transmitted by flies, as well as prevention of high densities of pest mosquitoes and other biting flies, are suggested as the modern counterparts of the former disease-specific type of approach on malaria, yellow fever, typhus, and plague control programs. It also is pointed out that enabling legislation is important to further growth in the field of vector control and that adequate and generally applicable principles should be developed to provide a satisfactory basis for further action by all states and affected communities. Furthermore, licensing laws for commercial pest control operators need wider application.

In the body of the report a brief historical background is presented which is followed by discussions of the legislative and administrative status of vector control programs and the scope of current activities. Of special interest to this group, perhaps, are data from Public Health Bulletin No. 184, published in 1950, entitled "Distribution of Health Services in the Structure of State Government," which show the department of state government which is responsible for various types of health services including mosquito and other insect control. It appears that among the forty-eight states, the District of Columbia, Alaska, Hawaii, Puerto Rico, and the Virgin Islands, the health department has responsibility for mosquito control activities in thirty-three instances, the department of agriculture is responsible in eight, State Universities are responsible in ten, and other agencies (conservation, highway, special boards, etc.) are responsible in nine. In twenty of these jurisdictions, however, responsibility for the work is divided among two or more of the agencies. Only five states reported no designated State agency with responsibility for mosquito and/or other insect control (Minnesota, Montana, New Hampshire, New York, and West Virginia).

By polling State health departments, other data were obtained which refer to the extent to which vector control programs actually are carried out by these state agencies. Replies to the poll were received from thirty-three states which reported on a total of 2,268 vector control projects. Of these, 734 were for mosquito control, 682 for fly control, 512 for rodent control, and 340 for general insect control. Many in this last category were concerned predominantly with mosquito and fly control. By number, municipal projects comprised 87 percent of the total. The larger and more significant projects tended to be district-wide or county-wide. The commonest type of municipal project involved the use of fogging machines or aerial sprays for killing adult mosquitoes and/or flies. Data regarding annual expenditures for vector control were particularly incomplete. This information as reported for less than one-third of the projects totalled $9,500,000, and of this total over $8,000,000 (84 percent) were being spent for mosquito control. Pennsylvania reported the largest number of projects (300), but expenditures were greatest in California, over $2,800,000.

The report concludes with the following paragraphs:

"It seems evident from the foregoing, that vector problems in the United States have many facets. Some of these environmental problems lend themselves to solution through efforts of individual householders with or without assistance from commercial agencies. Some are well integrated into municipal sanitation practices, while still others are handled as categorical programs dealing with the control of a disease entity or community-wide insect or rodent control. Only a beginning has been made in this report toward analyzing the entire situation. From our study, the conclusion has been drawn that the complex and important activity in this field of public health demands that it be given increasing attention by public health workers.

"They should study local needs and facilities and assist in promoting, organizing, and coordinating efforts to eliminate

vectors as menaces to the good health and comfort of the public. The problems of pest control are many. Research is constantly solving some of them, but new ones constantly develop. Nevertheless, progress is being made both in procedures and organization. It is recommended that succeeding vector control committees of the American Public Health Association work toward determining how health workers best can participate in and advance this work."

INSECT CONTROL IN MODERN MILITARY PREVENTIVE MEDICINE

JOHN M. HIRST

LCDR MSC USN *

"Sir: In my letter of June 19 (1864) I stated . . . that indications had forced me to the conviction that we were to have a season of yellow fever in this port (Key West, Florida). . . . It was evident that the first precaution to be taken was to get the vessels away from Key West, the center of the disease, as quickly as possible. . . . The vessels that have been detained here perforce have suffered severely. The steamer NITA was under repairs that rendered it impossible for her to get away. Every person on board but two officers has been taken ill of the fever and so far some ten or more have died. . . . I, myself, had the disease in a severe form. . . . The mortality on the island I am told has reached as high as 12 to 15 in a day. I concluded early in the program of the disease that it would be best for me to remain at this station. It is the only one from which the movements of the squadron can be properly directed or communication kept up with the North." This was written by Acting Rear-Admiral Theodorus Bailey, U. S. Navy, 27 July 1864.

A few years later, 1867, at Fort Jefferson on Dry Tortugas, our Military Preventive Medicine was sorely tried. "On September 2, the hospital at the fort contained 26 patients of whom 7 died. Major Stone, Commander of the fort, placed Dr. Mudd in charge of the hospital on September 6 and had him released from chains. . . . On September 13 every officer was ill except Major Stone. On September 15 Dr. Smith's son, 3 years old, became ill and died on September 18. . . . Major Stone, after this death, sailed for Key West with his two year old son to save him from the yellow fever. While enroute Major Stone became ill and died one day after reaching Key West. . . . The total number of cases was 270 with 38 deaths." This abstract is taken from the historical research material at Fort Jefferson.

At this time in American history the 39th parallel had taken on new significance and had been named the Mason-Dixon line. Less than a century later we are concerned over the bloody 38th parallel, only about 70 miles south of the Mason-Dixon line though several thousand miles west in Korea. North-south distribution is believed to be of minor importance in the distribution of insect life and it might be of relatively little importance politically as evidenced here. We must always be vigilant, however, and discontinuous distribution should ever be suspected. Many barriers and limitations which we thought impregnable have failed. Certain environ-

* The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the Naval service at large.

mental conditions which we think to be restrictive may give us a false sense of security due to our lack of conclusive direct evidence. Occasional *A. albimanus* along the south of Florida may be an example of this situation. "Seventy-five percent man hours lost due to mosquito bites" was reported in this state less than one hundred miles from this meeting ten years ago. Eighty-five percent of each regiment was reported ill with acute malaria at the fall of Bataan according to several observers. The cost of our lukewarm attitude toward malaria, early in the Korean campaign, is being paid at home as evidenced by the 1952 episode in California. Sylvan yellow fever which originated in Panama in 1948 is reported to be moving steadily in a north-west direction, practically unchecked. Infantile paralysis epidemics in Florida and Texas during 1946 and 1947 provided studies relating insect control to this disease. Insect control following the 1951 floods in the Kansas City area gave proof of our unpreparedness in this phase of health insurance.

Dr. J. C. Geiger, Oakland (California) Health Officer reported in August 1952, "The human encephalitis situation in the valleys of California so publicized at the present time is another shining example of delayed but obviously necessary public health work. In other words, often quoted, 'It is doing too little, too late,' an old public health custom in the United States."

In modern military preventive medicine we emphasize insect control in relation to the prevention and/or control of disease among members of our military forces and the conservation of health and physical fitness of troops. With few exceptions, this is analogous to the public health activities of our home space communities. In the examples which are cited in this paper, the close relationship of preventive medicine, *per se,* and military preventive is established. Some of you, either in uniform or in a civilian status, have volunteered or have been called to assist in various phases of military insect control. All of us look to the U. S. Public Health Service, the U. S. Department of Agriculture and other organizations for protection from insect disease vectors and pests. This symmetry of need brings us to a common appreciation of our problems. Through military service, many Americans are found around the world where they are faced with the difficulties of world health. It is impossible to find any group of people more highly trained and conscientious about their personal health than our men in service. As they practice preventive medicine in uniform, they are less likely to accept the explanation that "Our industry breeds flies, we will always have flies during this season," or "This city has always had mosquitoes and it always will." As these people return to their homes, they will be ardent believers in insect controls.

Malaria, bacillary dysentery, infectious hepatitis, dengue and filariasis are diseases of major importance to Naval personnel. Cholera, plague, amebiasis, typhus fever, schistosomiasis and relapsing fever are listed as diseases of secondary importance. Of these twelve diseases, arthropod vectors are known for at least nine. There is still some question as to the mode of transmission of some of these diseases just as there are some diseases which we have failed to recognize. "Mosquito-bite fever" and "sand-fly" fever are names of illnesses which, lacking known parasites, have not been accepted.

The incidence of intestinal diseases can be reduced to neglible proportions by environmental sanitation and immunization; vaccination will prevent smallpox; chemical prophylaxis affords a method of checking venereal disease; and, in fact, the only important epidemic diseases for which no positive control measures are available are certain of the respiratory infections. As for insect borne diseases, they can be practically eliminated by the application of insect control measures.

Our medical officers and your public health directors are faced with the proper control of many new toxic chemicals to prevent serious accidents due to negligence or ignorance of those who use these powerful insecticides. Fortunately there have

been very few known deaths reported to have resulted from many of our new insecticides. Military preventive medicine has established certain regulations in keeping with available test data so that only those who are qualified may be trusted to handle and use these poisons. In some instances these limitations have been too restrictive but in other cases we have been very lax. The American Mosquito Control Association can be a valuable source of information and assistance in bringing these safe practices into the techniques of the operators.

We have reached a new emphasis for Insect Control in Modern Military Medicine. The importance of producing the best combatant and preserving his health is paramount in our up-to-date military organization. To teach him personal protection against insect borne diseases is a vital part of his preparation. As he is sent from one situation to another he is informed of the known diseases in the new environment and the best methods of self protection. He is aware that everything possible is being done to protect him while in these varying positions. He is taught to recognize many of the common ecological associations and can evaluate these for himself. If military maneuvers preclude the practice of modern environmental sanitation, he is prepared to maintain his good health by proper clothing, repellents and suppressives. Medical schools are increasing their instruction in medical entomology and the effects of this training are noted in the field.

Our military aircraft fly many scheduled and unscheduled flights around the world. Most of these airplanes are equipped with the very best and latest instruments and engines. Some of these have complete installations for instant and simultaneous disinsectization of all compartments, wing spaces, tail sections, bilges and wheel wells. Those that have not been so outfitted are treated by conscientious orderlies of crew captains. Many of our continental and overseas bases are practising the most efficient permanent insect control measures as directed from within the military and as recommended from civilian experts and advisors. Temporary control techniques are programmed and directed by specially trained and experienced personnel. The most effective insecticide dispersal gear is in use on military aircraft where large areas require treatment. Ground equipment is still lacking on some bases but continued procurement is constantly relieving this shortage. Since many of these installations are operated in coordination with a foreign country, an excellent opportunity for coordination in insect control is present. To discuss mosquito control with Moroccans, Libyans, Koreans, Panamanians, Hawaiians and Japanese has been an exciting education. Insect control is one phase of preventive medicine which is simple to demonstrate and which proves its benefits rapidly. In fact, DDT is almost a universal introduction to conversation in any country today.

Prior to the advent of modern military preventive medicine, the concentration of any considerable number of troops, especially recruits, was in most instances accompanied by the occurrence of epidemics. In many campaigns, insect borne diseases prevented the full achievement of the military mission and even led to defeat. Where typhoid fever and dysentery raged practically unchecked, where typhus and plague marched with the warriors, where malaria and dengue caused more casualties than the enemy, modern military preventive medicine has found its place. The chapter on insect control, though it may contain some uncertainties, is worthy of its high position in preventive medicine in combat and at home.

USE OF RADIO IN MOSQUITO CONTROL PUBLIC RELATIONS

C. T. WILLIAMSON

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Through the use of local radio broadcasting stations, an opportunity is available for Mosquito Control Districts to bring to the people of the District the mosquito control problem existing therein. This is an ideal medium to use to gain the support and cooperation of the householder. It would seem that the majority of people who are troubled with mosquitoes are willing to help themselves if they can be told what to do. This public support is a feature mosquito control must have if it is to be successful.

In recent years, the number of small local radio stations has increased greatly and with it their value as a means of public relations. It is not necessary to reach the millions of listeners which the major networks do. The majority of people tend to skim a newspaper, reading only the headlines and articles of real interest to them, but by using the radio as a means of getting the subject of mosquito control to the public, a larger percentage is reached. The program should be directed to the householders, and, therefore, should be presented in language they can understand. The basic material is not the most interesting, but must not necessarily be presented that way. Probably the best format is the question and answer type. This interview is best used on programs designed to appeal to women. Questions and answers should be formulated by the mosquito control organization. The announcer, as the questioner, can ask the questions which are uppermost in the minds of the listeners. If there is any doubt as to the type of questions, ask your friends and neighbors. The question of the time of day when this program should be broadcast is very important. Most small stations are on daylight schedules so it has to be done during the day. On week-ends, a portion of your regular listeners will listen to one of the major networks unless the local station's programs are especially good. It is advisable then, to place your program either in the late morning or early afternoon. By selecting this time of day, most of your listeners will be women and so your talk should be directed to them. Explain to them how ordinary objects around the home can easily become a breeding place for mosquitoes. Bird baths, fish ponds (without fish), vases with unchanged water, depressions in cellar floors, uncovered pans and barrels with rain water. Stress the necessity for covering all vessels which might contain water or get rid of them altogether. Keep the fish pond well stocked with fish which will eat the mosquito larvae; change the water in the bird bath regularly. Recommend a spray which the householder can use easily but which will not harm plants or animals, especially in case of fish. Indicate how often and in what quantity these sprays can be used and what result to expect.

The spot announcements are, in my opinion, of great value in radio work. We might take a lesson from the large advertisers on radio, such as soaps, beers and cigarettes and note the number of spot announcements these people use during a day. Just a few sentences at the station break. This, perhaps, is the time when more people will hear your message whether they want to or not because they will not turn the radio to another station to avoid a ½ minute statement that is being said to them three or four times a day.

Radio stations will usually be very willing to cooperate and offer suggestions on this type of program. It is generally listed as a public service and a part of a station's success depends upon the quality and usefulness to the public of its public service programs. If the format is planned carefully, it can be kept to a ½ to 1 min-

ute spot whereas a half hour show can drag out and become very dry.

In conclusion I would like to suggest three facts to keep in mind when developing a program of this type.

First: The program is classified as a public service feature and your radio station is constantly seeking the program designed to serve the immediate community.

Secondly: Use plain layman's English. By no means get technical. And

Thirdly: Be repetitious. If we say the same thing often enough it will make the desired impression.

MALARIA IN TRINIDAD, ITS INVESTIGATION AND CONTROL . . . PAST, PRESENT AND FUTURE

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The Crown Colony of Trinidad and Tobago consists of these two islands lying within a few miles of the continent of South America off the coast of Venezuela and 10° north of the equator.

Trinidad is roughly rectangular in shape with large promontories on the northwest and southwest. The area of the island is a little more than 1,800 square miles and its greatest length is 50 miles from north to south with its greatest breadth 32 miles from east to west. The population of the Colony is given in the 1946 Census (1) as being 557,970 made up of approximately 15,000 whites, 340,000 black and coloured, 195,000 East Indians and more than 6,000 Asiatics. Port of Spain, with a population of about 110,000, is the largest city of the Colony.

Tobago is situated 18 miles away from the northeastern corner of Trinidad. It is a long and narrow island with an area of 114 square miles and a population of nearly 30,000 people.

The mean annual rainfall in Trinidad is 70 inches and in Tobago 72 inches. The population of the Colony is largely engaged in agricultural pursuits, the chief of which is the cultivation of sugar cane and cocoa. The existence, however, of the Pitch Lake and the occurrence of oil in Trinidad have given rise to a certain amount of industrialisation which is playing an increasingly important part in the economy of the Colony.

HISTORY OF MALARIA AND MALARIAL INVESTIGATIONS

Malaria was undoubtedly prevalent in both islands long before they came under the British Crown but the early records are meagre and throw little light on the subject. The capitulation of Trinidad to the British by the Spanish took place in February 1797.

At that time, a huge Spanish fleet lay at anchor under Admiral Apodaca in Chaguaramas Bay. It was unable to go into action due to the incapacitation of a great number of sailors with fever and fluxes as described by one Dr. Alexander Williams, the leading medical officer in Trinidad at the time.

The first British Governor of the Colony, Colonel Picton, who subsequently fought and died at Waterloo, reported the occurrence of a considerable amount of slow fevers, agues and fluxes among the Garrison troops, and in 1798 recommended that the capital city be shifted from Port of Spain to the heights of St. Joseph, ten miles away. Subsequent reports indicated

the continuance of a considerable amount of fever in the Colony though there are no records of any outstanding epidemics.

As recently as 1938, the amount of malaria in the Colony was alarming and the disease then constituted the major public health problem of the Colony. The number of admissions of malaria to the Colonial Hospital in Port of Spain in the five-year period from 1929 to 1933 was a little more than 5,000 cases of malaria and 38 cases of black water fever (2). In the period 1934 to 1938, approximately 6,500 cases of malaria and 42 cases of black water fever (3) were admitted to this institution. In the period from 1947 to 1950, however, the number of cases of malaria admitted was 1,105 with no records of any case of black water fever (4).

The annual number of deaths from malaria as reported by the Registrar General (5) have shown a considerable decline. In 1931, 740 deaths were recorded, in 1941, 493 and in 1951, 136.

With the establishment of the role of the *Anopheles* mosquito in the transmission of malaria at the commencement of the century, the local Health Department began to devote much time and study to the mosquitoes of Trinidad and Tobago. In 1901, the Secretary of State for the Colonies drew attention to the advisability of instructing the public with regard to the relation of malaria to the mosquito and instituting precautionary measures against contracting this disease. In 1908, antimalarial measures were specifically recorded for the first time. Boyce (6) in his "Health Progress and Administration in the West Indies," published in 1909, lists five species of anophelines in the Colony and makes mention of the investigations that Mr. Urich, subsequently Entomologist to the Imperial College of Tropical Agriculture, was carrying out with regard to the anophelines of the Colony. He wrote as follows—"Mr. Urich is describing a bromelia anopheline which he thinks may be a source of malaria upon the cocoa and other plantations . . . (namely) *A. bellator*, D. & K. . . . a forest inhabiting species living only in Bromeliae. It is found in hills where there is no ground water. It is also found on cocoa estates, where Bromeliae are allowed to thrive in abundance on shade trees, common in forests all over the island and on many cocoa estates. My (Urich's) attention has often been called to the fact by country people that fever is prevalent in recently felled land: I put it down to this species and not to *A. tarsimaculata*." The number of known anophelines was increased to seven in Urich's (7) paper "Mosquitoes of Trinidad" in 1913. He says: *"A. tarsimaculata* is the commonest anopheline occurring all over Trinidad wherever favourable conditions exist, namely man and suitable breeding places near his houses. It is the principal carrier of the malaria parasite, if not the only one." Lassalle (8) increased this number to eleven in his 1913–1916 reports, and in his 1920 report (9) states that *A. albipes (aquasalis)* and *argyrotarsis (albitarsis)* convey malaria in the Colony. de Verteuil (10), in 1925, states: "The studies of Darling and others in Panama leave little doubt that *tarsimaculatus* and *albimanus* (which form about 80 to 90 per cent of the total number of anophelines in the populated parts of the Island) are here the usual carriers of benign tertian and quartan fevers. The following observations, made over a number of years, have led me to believe that the usual carriers of malignant tertian are *argyrotarsis* (*albitarsis*) and *maculipes* (*neomaculipalpus*), or both. Together they constitute about 5 to 10 per cent of all *Anopheles* and have been found in most parts of the Island." In his 1930–1934 reports (11) de Verteuil fully established the importance of *A. aquasalis*. He showed this mosquito to be the main vector of malaria in the swamp and riverine areas of the Colony and adduced excellent epidemiological evidence incriminating *A. bellator* as the main vector of malaria in the high rainfall cocoa bearing areas. This finding was eventually confirmed by the work of Rozeboom and Laird (12) in 1941. They dissected 725 mosquitoes and found three infected, two with oocysts and one with salivary gland infection and they also succeeded in infecting the species ex-

perimentally. This was the first time that a member of the subgenus *Kerteszia* had ever been implicated definitely as a vector of malaria, although various species of *Kerteszia* in other countries had likewise been suspected (13, 14).

With the coming of World War II and the establishment of American bases in the Caribbean islands, several distinguished workers in malaria visited the Colony. Foremost among these were Colonel W. H. W. Komp and Dr. Mark Boyd. To the latter was mainly due the establishment in 1941 of a fruitful period of cooperation in malaria investigation and control between the Government of Trinidad and Tobago and the Rockefeller Foundation. The report (15) of the comprehensive malaria survey of the Colony so jointly undertaken constitutes the basis of subsequent malaria investigations and its control. The report showed:

1. That about one-half of Trinidad is practically malaria free.

2. High malaria rates are widespread in northeast Trinidad, (15 of the towns here had rates ranging between 21.3% to 81.6%) and in a number of smaller and rather widely scattered coastal portions of the Island. Tobago, likewise, has high malarial rates in several population centres.

3. Thirteen species of *Anopheles* occur in Trinidad, four of which have not been previously recorded in Trinidad. Another species (*A. pseudopuntipennis*) which undoubtedly existed here previously could not be found in spite of intensive search.

4. Only two of the *Anopheles* are dangerous malaria vectors, *Anopheles aquasalis* and *Anopheles bellator*. The former is responsible for most of the malaria in the two islands, chiefly that found along the coasts. The latter breeds in the "Wildpines" (wild plants of the pineapple family or the epiphytic bromeliads) which grow in great abundance in the cocoa plantations. The spleen rate among school children in eight towns in the high rainfall cocoa zone of Trinidad ranged from 21.3% to 56%.

5. Dissections of 1,364 house-caught *Anopheles aquasalis* gave an oocyst rate of 3.3%; only one salivary gland positive was found in the series. A total of 1,263 *Anopheles bellator* dissections produced an infection rate of 0.78%; no salivary gland positives were encountered.

6. Malaria therapy for the treatment of general paresis was initiated in St. Ann's Mental Hospital. Nine Negro patients were treated with *P. falciparum* and one white patient with *P. vivax*.

7. In experimental feedings (conducted in connection with the malaria therapy) *Anopheles aquasalis, Anopheles bellator* and *Anopheles albitarsis* were found to be very susceptible to *P. falciparum*. *Anopheles oswaldoi* and *Anopheles neomaculipalpus* proved too refractory in their feeding propensities to supply sufficient data for satisfactory conclusions.

8. *Anopheles aquasalis* appears to be the only vector of malaria in Tobago.

9. The malarious parts of Trinidad may be roughly divided into two categories, the "over-head" malaria districts and the ground-water malaria areas. In only a few localities do the two malarias combine. Obviously the time honoured system of oiling ground waters must give way to new types of malaria control measures in the localities where overhead waters are responsible for the presence of the disease.

10. The urgent need for the study of the Bromeliaceae and *Anopheles bellator*.

In subsequent years, taxonomic and ecological studies on the bromeliads were carried out by C. S. Pittendrigh (16) and have yielded both practical and academic results of considerable value. Seven species of Bromeliaceae new to the local flora were discovered, and 59 species were listed as occurring in the Colony. The ecological studies have permitted a "natural habitat grouping" of the species which serve to explain the geographical distribution of the plants in Trinidad and Tobago. The peculiar structure and physiology of the plants render them susceptible to plant poisons. Owing to the arboreal habitat of the plants, they have developed funnel-shaped forms which enable them to collect and maintain reservoirs of water over long periods of time, hence one of their common

names, "tank plants." Further, their leaves, particularly in their lower portions, have absorbing scales—a structure unique in the plant kingdom—which enable them to absorb this water and nutriment as well. These features provide an avenue of attack which is considerably faster and more economical than the obvious manual removal. The plants are readily killed by dilutions of plant poisons which have not the slightest effect upon the vast majority of other vegetation.

In 1948, Major R. A. Senior-White, was appointed Entomologist, Malaria Division, Trinidad and Tobago, and the preliminary studies that he has executed on the bionomics of *A. aquasalis* have been published in a large monograph "Studies of the Bionomics of *Anopheles aquasalis* Curry, 1932" (17). The discovery of daytime resting places of *A. aquasalis* and the evaluation of blood preferences of *A. aquasalis* by precipitins are among the more important observations in this report. In connection with plant preferences in outdoor resting, considerable use has been made of an unique apparatus for microclimate studies. Penman's micro-humidity apparatus depends on the very rapid changes in resistance in a pellet of a mixture of oxides, a trade secret of Standard Telephones & Cables, Limited.

The pellet is placed in a glass tube about the size of a clinical thermometer, with wires leading to a variable resistance bridge. A calibration curve, (individual to each tube, which is termed a "thermistor") serves to turn resistance into temperature. Two closely mounted thermistors, one gauze covered, serve as dry and wet bulb thermometers. Measurements can be made in a ¾ inch diameter area. The apparatus, as at present designed, is untrustworthy in light of >500 f.c. or a strong wind. Only 7½% of *aquasalis* resting is at >500 f.c., and there is little air movement in the bottom foot of vegetation. The apparatus works on standard torch dry cells, and is easily portable. It is not on the market and the only two instruments in existence have been built by technicians from odd parts purchased separately. A modification of the thermistor design so that the dry and wet bulbs do not interfere with one another by radiation or wet bulb moisture is being explored.

In spite of the publication of the large monograph referred to above and three subsequent papers in press, our knowledge of *A. aquasalis* contains notable lacunae. In particular, we do not know with any exactitude its optimum flight range either in dispersal or directly to blood. It is so difficult to mass breed and so delicate when tube caught that significant results may be obtained only with the aid of P^{32} in the larval food and a Geiger counter. The survival of eggs on mud free of surface water was first brought to attention during the attempted malaria eradication program in Tobago and is now under laboratory investigation. Predation still requires detailed study, and natural oviposition of this mosquito is yet to be seen.

In addition to this program of work with *A. aquasalis,* work is proceeding with regards to *A. albitarsis, A. neomaculipalpus* and *A. eiseni.* This latter mosquito breeds in hillside streams and the adults are found resting between the buttress roots of forest trees. It does not rest on grass and shrubs nor among bamboo stools nor dark holes in the bottom of cocoa bushes. It has been taken on rocks, in shade and in stronger light among moss and rocks. It seems to remain close to its breeding water and bites man readily.

Anopheles neomaculipalpus may be a vector of secondary importance in the transmission of malaria and considerable study will have to be devoted to this mosquito as well as to *Anopheles albitarsis* of which little is known of the larval ecology. This latter mosquito is virtually absent from December to June in areas where it is taken in extremely high densities during the rainy season. How it passes the dry season is not known and it is a likely suspect of the low malaria endemicity of the inland plain.

Very little is really known of the widely differing biology of the two common local *Kerteszia.* They attack throughout the

day and at least during the early part of the night. Their dawn behaviour is unknown. They are stated hardly to enter houses at all but further study is required to confirm this. They have been recovered in open verandahs. A more exhaustive study of the bromeliad species preferences and productivity is being made. The ecoclimate of the forest where both *Kerteszia* breed needs detailed studies and already preliminary studies into the growth and regeneration of bromeliads have been undertaken. At the moment, the extent to which winds and birds play a part in dispersal and growth is under study. The replacement of copper sulphate sprays by other herbicides of the 2,4,D type opens new avenues of control. Their application presents many local difficulties calling for much experimentation.

Considerable work has also been done in evaluating the efficacy of residual sprays as well as some of the new insecticides against our local anophelines. Special attention is being devoted to the innumerable types of wall surfaces found in the Colony whose population consists of representatives of every racial group of mankind.

MALARIA CONTROL

Prior to the recognition of the role of the anopheline mosquito in the transmission of malaria, the usual time-honoured practice of dealing with malaria as a disease due to the emanation of noxious gases from the swamps was rigidly adhered to in Trinidad. We find the same Dr. Alexander Williams, to whom reference has been previously made, advising the Spanish Governor in 1795 to change the place of anchorage of their men-of-war to some other site where the men would breathe a more salubrious and purer air. Many of the early settlers in the Colony forsook the coastal regions for the densely wooded valleys of the Northern Range thereby contributing immensely to the early establishment of economic crops in these valleys. After 1900, the teachings of Gorgas and the lessons of the Panama Canal were put to good practical use by Dickson and Lassalle, two men who were keenly alive to the immense possibilities of improving malaria control and whose contributions were made at a time when few men were able to envision at its true worth the value of such a work.

The establishment of the sugar estates during the early years of the 19th century contributed greatly, through the adoption of a wise policy of drainage, to the comparative freedom from malaria of those areas in the Central Plain where one would normally have found much malaria. Owing to the clayey nature of the soil, deep and well-graded drainage lines had to be laid down and the drainage systems then established stand out, even today, as models for all others. In the cocoa bearing belt, from 1890 to 1914, large tracts of forests were cut down and gradually planted with cocoa.

It is unfortunate that the cultivation of cocoa was attended with the planting of shade trees of the *Erythrina* group, species particularly susceptible to the harboring of bromeliads. As a result of the mosquito infestation of these cocoa estates, it became a *sine qua non* that all houses were efficiently and effectively screened from the very earliest days.

With the discovery of oil in Trinidad, the operating companies immediately realised the benefits of protecting their employees from malaria. It is largely due to their thorough and progressive antimalarial policy despite limited knowledge, that in addition to the usual drainage and anti-larval measures, the screening of bungalows and improvement in medical assistance as well as in housing and living conditions of the labouring classes were rapidly established in their operational areas.

An important advancement in malaria control was the early construction of low tide culverts (18) to deal with the coastal drainage of the innumerable streams with which the Colony is favoured. Though these low tide culverts were, by and large, a failure, they pointed the way to the development of the self-clearing seaheads for low drainage through surf (19). A self-clearing outfall at low tide through sand

bars thrown up by surf action is necessary in order to keep open the mouths of many rivers, which have only a small dry season discharge, after the rains have ceased.

No attempt was made prior to 1941 to control bromeliad malaria largely due to the complexities of the problem and inadequate knowledge of the anopheline vector in the cocoa bearing high rainfall districts.

The present malaria control program of the Colony embraces the usual features of clearing, drainage and larviciding together with the execution of capital works such as the construction of self-clearing seaheads and the reclamation of seepage and swampy areas. In some instances, automatic siphon flushes have been erected and where the location has been suitably and carefully chosen, excellent results have been obtained.

In *Anopheles bellator* country, considerable progress has been made in the control of bromeliad malaria. Advantage has been taken of the peculiar physiology of the plants involved. Many technical and operational difficulties had to be overcome before a suitable machine could be got together to deliver a lethal but dilute solution of copper sulphate to the bromeliads.

The equipment used consists of a pump driven by a six-cylinder gasoline engine and capable of pumping the solution at pressures up to 2000 lbs. per square inch. The solution is prepared in two tanks attached to the pump and continuously agitated by paddles. An auxiliary pump fills the tanks with water from a pond or stream near which the equipment is located, and the required quantity of copper sulphate is added to make a solution containing ½% copper sulphate. The tanks are used alternately so that while solution is being pumped out of one, the other is being filled and mixed. The solution is taken into the field by 1″ reinforced high pressure rubber hose and is discharged in a solid stream through a 5/16″ nozzle at a pressure of 300–350 lb. so that plants growing 60–80 feet above the ground could be sprayed. The power of the pump makes it possible to spray trees as far as one mile from the equipment, which must be located near an adequate water supply since there is a nozzle discharge rate of 35 gallons per minute. This equipment is mounted on a truck chassis and has been in use in the cocoa areas of east central Trinidad since 1945. Over 4,000 acres of cocoa lands have already been treated and in the Sangre Grande district, where the work was first started, malaria (spleen) rates have fallen from 30% to 5% due to this method of control alone.

A residual DDT house spraying program has been executed since 1945 and this year, the program will be extended to every one of the estimated 160,000 houses in the Colony.

Tobago, the island ward of the Colony, has been the subject of a special malaria eradication project jointly sponsored by the Rockefeller Foundation and the Government of Trinidad and Tobago. The island itself has no very large swamps and *A. aquasalis* is the only vector of malaria. Seaheads and low tide culverts, swamp reclamation and the diversion of main drainage lines together with the usual temporary measures of control and a biannual application of DDT and Gammexane to all houses have been executed.

The net result of the intensive program of malaria control executed in the Colony has yielded most satisfactory results. In Tobago, the spleen rate which was nearly 20% before the commencement of the control program fell to less than 1% in 1951 and this reduction has been maintained in subsequent years. Tobago has already lost its old reputation as being one of the most malarious islands of the West Indies and is becoming more and more the holiday resort not only of Trinidad but of an increasingly large number of people from the United States of America and Great Britain.

In Trinidad, comparable results have been achieved particularly in the areas surrounding Port of Spain where the malaria rates were in the vicinity of 35% to 40%. Recent surveys have indicated that they are now less than 3%. Likewise in the north eastern promontory of the island where the highest rates were

found ranging from 60% to 83%, malaria rates have been held down for the last five years to less than 5%.

Given the continuing support of an enlightened Government and an intelligent interest in malaria control, it is not too optimistic to hope that by a process of attrition, and without the expenditure of sums beyond the economy of the island, malaria may yet disappear completely from the Colony within the next decade.

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THE PEST CONTROL OPERATOR'S PLACE IN MOSQUITO CONTROL

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Before being specific regarding the part that the pest control operator might have in the field of actual mosquito control service work, it seems to me that there should briefly be submitted two general observations.

In the first place, very little basic research work can be expected to be done by the PCO. Essentially the PCO depends upon governmental research personnel as well as manufacturers of chemicals and equipment to provide the answers regarding formulations and acceptable techniques of application for the elimination and control of mosquitoes.

Secondly, there is the common denomi-

nator that not only affects many attending this meeting, but also affects the pest control operators; namely, MONEY. Obviously for those who *are not* engaged in commercial or private enterprise, appropriations primarily derived from taxes must pay the bill. The PCO's must look to property owners, various industrial and business enterprises, and, occasionally, municipalities to pay for mosquito control services.

In short, *money* is perhaps the important factor for all of us. Accomplishments altogether too frequently hinge on available funds. Newspaper stories constantly remind us of what I commonly refer to as the "Battle of Appropriations." In connection with publicity early last month about the New Jersey Mosquito Extermination Society meeting, there also appeared an editorial in the Philadelphia Inquirer entitled *"Skeeter Bite Versus Tax Bite."* To quote one paragraph, "If the choice for Jersey folk is between a skeeter bite and a tax bite—maybe they'd like a little more evidence that suffering from the second will really cure the first."

* * * * * *

Having, therefore, made these two observations regarding the PCO's relation to basic and field research, and the "money" problems, I have no hesitancy to say that responsible pest control operators, and certainly the National Pest Control Association, recognize the fundamental aspects and need for continuing mosquito control programs. Spelling this out even further, I would like to emphasize our genuine interest in supporting sensible mosquito control programs involving appropriations. Without area-wide and/or permanent large scale maintenance, which we do not consider the pest control industry is in position to do, it would be folly on our part if we did not support such programs. To be selfish and very practical, it is to our advantage that we get behind the fundamental aspects of continued mosquito control programs, because the jobs to which I will subsequently refer can then be more satisfactorily done by pest control operators.

In short, at the National Association level we have opposed the efforts of a comparatively few PCO's who have resorted to high pressure methods or who have unjustifiably criticized some of the county mosquito control projects. Our attitude is that of supporting appropriations for area-wide projects but at the same time we expect that similar cooperation will be given to pest control operators to take over jobs for which they are qualified. The latter must naturally be based on the assumption that the pest control operator will give evidence of knowledge regarding mosquito control procedures. By "rubbing elbows" together we will both have greater appreciation for doing an all-round better job of mosquito control.

That now brings us to the type of jobs which might well be done by trained and experienced pest control operators. In discussing the specific type of jobs, I realize at times that there may be a little overlapping but generally speaking, I am convinced where there is an honest desire to cooperate, ways and means can be found to overcome possible misunderstandings. I shall enumerate and assign broad classifications of the type of jobs that are of interest to the PCO.

1—Control on fringes of area-wide projects: On the assumption that a county project is being done, there are also nearby areas or "spots" involving private homes or even small block-areas that might well be taken over by the PCO.

2—Large estates and private homes (the latter usually with spacious grounds) that do not necessarily comprise a part of a general mosquito-infested, large-scale or county project area, should be done by private enterprise. Lawn parties and out-of-doors picnics often become the basis for requests being made for mosquito control. Such services should be done by PCO's rather than a special service paid for out of general taxes.

3—Business and industrial properties that come within the same category just mentioned in the previous paragraph should be the job of the PCO.

4—Resort areas including hotels and

motels, private picnic areas, drive-in theatres, baseball parks and sports parks, fair grounds and the like: Should be done by PCO's. If complete cooperation prevailed, it would be a big step in the right direction toward a closer working relationship between government supervised and commercial mosquito control.

5—Summer camps, especially private camps, with their vested interests and operating for profit (or otherwise) should not expect general tax funds to pay for necessary mosquito control. To be sure, the overall problem may be due to certain conditions prevailing elsewhere on the lake remote from the actual location of the camp. It still should become an obligation of property owners on the lake to have mosquito control done by commercial enterprise.

6—Miscellaneous nuisance situations: A greater number of such exist than perhaps is realized and for the most part the PCO today receives nothing for his time but considers it a part of good customer relations to assist. I am thinking of the many ways in which stagnant water is allowed to accumulate and breeding areas in unusual places exist. Poor drainage conditions, careless sanitary practices, pools of water that continue to remain, etc. are a few of the situations. This type of service primarily calls for advice. It is easy to see that it costs money for PCO's to inspect when such complaints are made and discuss remedial measures which do not involve any chemical or pest control services. There should also accrue a few mosquito control jobs. The important point I am trying to make is that the PCO should be expected to provide this type of service.

In summary, therefore, I cannot help but repeat in perhaps somewhat different language that pest control operators cannot expect to do ditching, draining, etc. for salt marsh mosquitoes or engage in large operations such as dredging, stream straightening, dikes, dams, water level regulations, etc. for the fresh water groups. On the other hand, these and related operations are sometimes so expensive and spectacular that they overshadow other methods and give the impression that nothing less can be done. It would appear that the public and pest control operators themselves may for too long a time have been accustomed to this attitude, whereas all of us should realize that there is room for small scale mosquito control operations (on a contract basis through commercial enterprise) to provide mosquito control services. My purpose will have been served if I have offered specific types of jobs that can and should be done by competently trained and experienced PCO's who in turn would also recognize the importance of working cooperatively with Mosquito Abatement groups.

Continued from page 59

techniques have a special applicability to work with mosquitoes, or who have discovered some special manipulative detail for handling mosquitoes in experimental procedures, have also been more or less frequent contributors to *Mosquito News*. But the field workers who make an improvement on a ditching machine or overcome, on the spot, an unanticipated floodwater or tidal problem, are inclined to consider it all in the day's work, and to let it go unrecorded.

The Editor urges all field workers, therefore, to record their observations, accomplishments and ideas for the meetings and for *Mosquito News*. Only in this way can we achieve the desired balance between "scientific" and "practical" articles.

MALARIA MOSQUITO CONTROL AT THE JOHN H. KEER RESERVOIR

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Introduction

The John H. Kerr Reservoir lies between South Hill, Virginia, South Boston, Virginia, and Henderson, North Carolina. U. S. Route No. 1 passes within 6 miles of the dam. The reservoir is 39 miles long with a total shoreline of 800 miles. At average pool level the reservoir covers 48,900 acres. This Corps of Engineers project is a multipurpose development for the control of floods, hydroelectric power, low river flow regulation, and recreation.

The 1952 malaria mosquito control program at John H. Kerr was conducted by an entomologist, 3 control aids, a labor foreman and 6 laborers.

Control Program in 1952

Aerial Spraying. Aerial spraying was the principal method of control and the work was done on a contract basis. The contractor's equipment consisted of a Piper Cub, specially fitted with Art Whittaker attachments, which included a 47 gallon belly tank suspended between the landing gear, a wind driven pump, and a spray boom beneath each wing.

Spraying Systems Tee-Jet nozzles were installed at each wingtip and on one wing inboard. All other apertures in the booms were sealed. Pressure was varied according to the nozzle size and the exact amount of insecticide to be applied.

A 20% solution of DDT in Sovacide 544B was applied at the rate of one tenth to five hundredths of a pound of DDT per acre when used as a larvicide, and two to three tenths of a pound per acre when used as an adulticide.

Glass slides, coated with General Electric SC 87 Dri-Film, a water repellent silicone fluid, were used in the determination of particle size. Droplets of from 100 to 150 microns were used in larvicidal work, and droplets of around 50 microns were used while spraying for adults. The plane was flown at 80 m.p.h. approximately 35 feet above the surface, giving it a swath width of 70 feet.

Aerial spraying, conducted 3 to 4 days per week, was confined to the early hours of the morning and early evening hours. Limited adult spraying was done in areas of high human inhabitance when adult mosquito collections indicated the need. This was always done in the evening. At the end of the season we had used 15,263 pounds of DDT, 7,155 gal. solvent and had flown 236 hours.

Larviciding by Boat. Because of incomplete inundation last year, boat application of larvicide was limited to a few deep water areas. Two flat bottomed inboard motor boats were equipped with pumps to discharge water and 5% DDT in solvent. The rate of application was about one tenth of a pound DDT per acre.

Hand Larviciding. Wherever the labor foreman discovered mosquito breeding while performing other work, larvicide was applied by hand from portable compressed air sprayers. This also was applied at the rate of about one tenth of a pound of DDT per acre.

Shoreline Maintenance. The labor foreman and six laborers spent most of their time last season on marginal drainage and growth removal. Because of this limited manpower, work was carried on primarily in populated areas.

Results of Control Program

The 1952 season was one of greatly increased mosquito production in the reservoir area, even though there were then only 250 to 300 miles of shoreline. This was due largely to two main factors. First, the reservoir basin of 48,900 acres had been cleared by heavy equipment which left

countless depressions in the soft, flat bottom land. In these, both pest and *Anopheles* species reproduced prolifically. (*A. quadrimaculatus, A. punctipennis,* and *A. crucians* are the predominant *Anopheles* species in the reservoir area.) Second, partial inundation was taking place during August and September—the peak mosquito months.

The greatest problem last year, however, was in trying to keep informed as to where mosquitoes were breeding or being controlled as well as carry on other phases of the work, with only a few men.

In appraising our program we relied upon larval dipping to determine the immediate effectiveness of larviciding, adult counts from collection stations to determine general adult population trends, and a comparison of adult population records of previous years to determine overall control results.

The appraisal of last year's mosquito totals as compared with mosquito incidence of previous years was most difficult as the ecology of the reservoir was markedly different. A few adult counts the previous year in 1951, ran as high as two and three thousand *A. quadrimaculatus* per station, per visit, while last year the same stations yielded less than a half dozen per visit. A few other stations, particularly where late summer inundation took place, gave counts of 1 to 40 *A. quadrimaculatus* where none had been taken the year before. Station totals such as these increased or decreased depending upon the amount of attention given their respective areas. However, the majority of 92 adult stations showed less than 10 *A. quadrimaculatus* per visit during the season.

There were no reported cases of malaria, nor complaints of annoyance filed with the Virginia or North Carolina State Boards of Health nor with the Corps of Engineers Office in 1952. We were therefore not displeased with the year's work.

REBRUSHING

A rebrushing program was conducted in 1952 through 1953 by an Entomologist in charge, supervisor, 3 labor foreman, and 65 laborers. The removal of secondary growth in certain areas of the reservoir was planned primarily for mosquito control. Flat and sheltered bights and embayments lying within the top 8 feet of the fluctuation zone were therefore earmarked for rebrushing. As *Anopheles* mosquito production is directly proportional to the amount of intersection of the water surface, stiff-stemmed annual growth in the upper zone of fluctuation, which was not expected to deteriorate with partial inundation, was therefore cut along with perennial growth.

Work was done by hand tools and mechanized equipment. It was found that tractor work was faster and not unduly expensive when the equipment worked; however, keeping it in good repair was difficult. Experienced tractor operators were unobtainable, stumps and rough terrain caused breakage, and the vast marshy areas could not be negotiated by the tractors. A set of "half tracks" would have helped considerably in marshy bottom land had they arrived in time for use. Rains and the rising reservoir maintained wet areas which consequently resisted "area burning." Cutting, piling, and burning by hand was very slow, but dependable and least expensive.

In March, when the rising reservoir ended the work, 1,813 acres had been rebrushed.

PROGRAM CHANGES AND ADDITIONS FOR 1953

PERMANENT MEASURES. Changes in program for the 1953 season will be directed toward permanent control measures wherever possible. Dynamite will be used to blast large permanent ditches thru hundreds of acres of marshy bottom land in order that those areas may be drained upon recession of the lake. Ditches will also be dynamited to eliminate marginal pools and swamps where hand ditching is impractical.

The Island Creek subimpoundment will be closely studied this season to determine the feasibility of "deepening and filling"

certain shallow water areas. In this method, the lower part, or that portion of a marshy area toward the lake, is deepened and the earth obtained is spread upon the upper half of the marsh. Such displacement of earth creates a steep bank of 2 to 4 feet, and is a permanent method of eliminating trouble areas. Unfortunately, this would not be practical on the main reservoir as the 8 foot seasonal recession would pull the water below the bank and the deepened area before the end of the breeding season.

GROWTH INVASION STUDIES. In order to observe the extent of marginal growth invasion, lines of stakes at about 6 inch contour intervals will be set in typical areas around the reservoir. Mosquito production and larvicidal expenditures may later be correlated with this growth invasion index.

AERIAL SPRAYING. A 30% DDT solution will replace the 20% solution used last year. By doing this a saving is anticipated in both flying time and solvent. In the way of deterring mosquito resistance to DDT, greater effort will be made to apply only minimum dosages to larvae this season. A large scale experimental adulticiding program will be done by airplane in the evening and the results determined by biting counts and light traps.

NOTES ON THE ACTIVITIES OF *AEDES* LARVAE

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INTRODUCTION: Animals which feed by the filtration of a stream of water are commonly sedentary or sessile. This is apparently partly because they can bring food to themselves instead of having to go and fetch it, but more because this method of feeding rarely permits the accumulation of sufficient energy reserves for extensive or violent movement (e.g. Jørgensen, 1952). If the characteristic wriggling of mosquito larvae is their normal activity state, as many writers apparently believe (e.g. Matheson, 1944, pp. 31 & 32) they represent a striking exception to this in that they are left with sufficient energy reserves to permit an unusual degree of activity in the pupal stage also.

These observations were made in an attempt to elucidate this riddle, and as a preliminary to more extensive studies of the energetics of the mosquito adult (Hocking, *in press*).

Diurnal movements: Most observations were made on a large population of larvae of *Aedes communis* De Geer in a single pool (fig. 1) near Churchill, Manitoba.

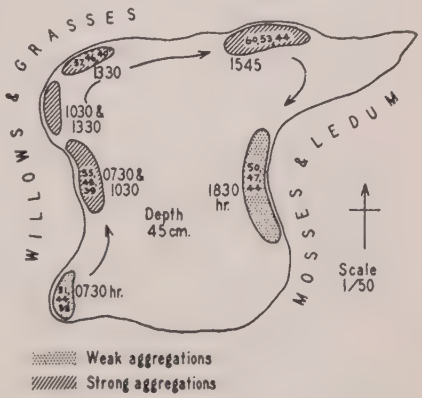

FIG. 1. Changes in the position of aggregations of the larvae of *Aedes communis* through the day. 5 June, 1951. Figures within the aggregations are fahrenheit temperatures at the top, middle depth, and bottom.

This was watched for total periods of up to 6 hours on selected days during larval development. There were few larvae of any other species present.

On sunny days, when the larvae were mostly in the 2nd or 3rd instar, they formed conspicuous aggregates which permitted the observation of a general circulatory movement around the pool. Aggregates were formed at the surface of the pool, in the shallows which were receiving sunlight most strongly, and were never seen on a completely overcast day. Up to 1003 larvae were obtained in a single dip with a 400 cc. dipper from aggregates; the average number elsewhere in the pool was 20, most of them 1st or 2nd instar.

To investigate the direct effect of sunlight, a dipper of larvae was placed in the sun so that one half was shaded. In a few minutes, most of the larvae had assembled in the shaded side (fig. 2, top.) The dipper was then rotated through 180°, so that the shaded and sunny sides were reversed; this was done slowly so that the water and larvae moved with the dipper. The photograph in fig. 2, bottom, was taken 30 sec. after this reversal; the intense aggregate in the middle of the sunny side persisted for 4 or 5 minutes, breaking up by the movement of larvae from the margins, towards the shaded side of the dipper. It seems that, in spite of the photokinesis resulting in a general tendency to aggregate in the shaded area, sunlight may contribute to the formation at least of temporary aggregates, presumably through a form of the phototelotaxis described by Muirhead-Thomson (1940) for *Anopheles minimus,* the larvae orientating mutually towards their shadows.

Temperature perhaps may play a more important part in the formation of aggregates than light; Ivanova (1940) has shown that the larvae of *Anopheles maculipennis* when placed in a temperature gradient tend to move to an optimum temperature zone. The temperatures at the top, middle depth, and bottom, taken at the time of the first observation after aggregation are shown in fig. 1. On only one occasion were temperatures higher

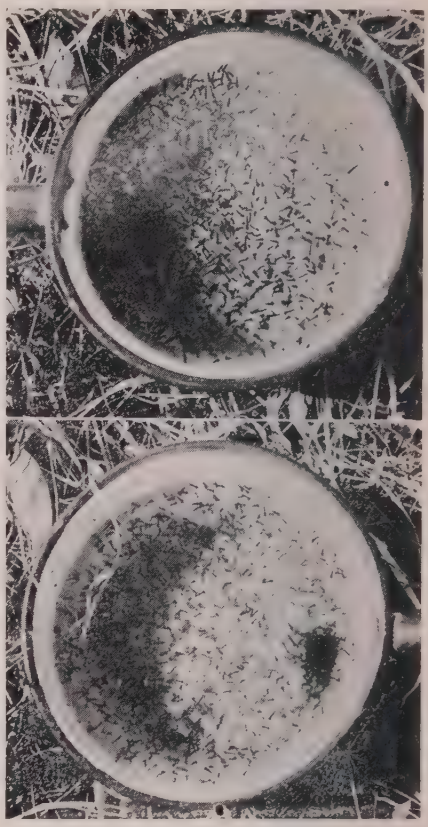

FIG. 2, top. Larvae of *Aedes communis* aggregating in the shaded side of a 400 cc. dipper.
FIG. 2, bottom. 30 seconds after rotating the dipper through 180°. Aggregates forming in the sun and shade.

than those in existing aggregates recorded elsewhere in the pool; at 1545 hr. the temperatures near the SE corner were 61, 52, 43° F.

Under undisturbed conditions there appeared to be little activity beyond local feeding movements, and this steady drift of aggregates around the pool on sunny days.

Methods of progression: These diurnal circumnavigations appear to be accomplished with little assistance from the supposedly normal wriggling method of loco-

motion. Nearly all motion was with the aid of the feeding current set up by the mouth brushes. Indeed there were only three circumstances in which wriggling appeared to be the normal activity. Firstly, as an alarm reaction in response to a major disturbance; secondly, in coming up to the surface after diving; and thirdly, a very brief action in breaking away from the surface film for a dive. All other movements, at or below the surface were accomplished by means of the mouth brushes; a much more economical activity.

Presumably the movement of the mouth brushes which is used in locomotion is similar to that used in the "interfacial feeding" described by Renn (1941) in *Anopheles quadrimaculatus* and *A. crucians*, which would give a larger resultant force than would eddy feeding. It is evident, however, that the direction and magnitude of the force can be precisely controlled; the effect of this can be seen in the variation in the angle at which larvae hang from the surface film (fig. 3). Surface

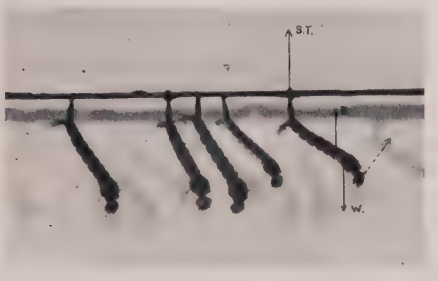

Fig. 3. Angles made by larvae of *Aedes communis* with the surface film.

tension acts vertically upwards at the tip of the siphon which serves as a pivot. The buoyancy of the water acts vertically upwards at the centre of buoyancy. This is probably posterior to the centre of gravity, at which the weight acts vertically downwards, since the tail is normally above the head. Mosquito larvae are usually slightly heavier than water, that is, the weight is slightly greater than the buoyancy. If larvae are to hang in any position in which the centre of gravity is not vertically below the siphon, an additional force is necessary with a moment about the tip of the siphon proportional to the sine of the inclination of the body axis to the vertical. This force seems to be provided by the reaction set up by the feeding current.

The force resulting from the feeding current is apparently also utilized in a peculiar variant in feeding behaviour which has been observed especially in the younger larvae of *A. communis, A. pionips,* and *A. stimulans* and probably other species. This involves a circling movement which has been mentioned by Bates (1949). The larva lies parallel to the surface after the manner of *Anopheles spp.,* but the head is not reversed, and the food current comes from below the surface. The larva rotates about its siphon. There may be an overall movement in one direction superimposed on this, so that the path travelled by the head approaches a cycloid. This movement seems to be accomplished by a twisting of the head about the long axis of the body—an approach to the completely reversed condition of *Anopheles*—this brings the mouth brush on one side closer to the surface film which perhaps enhances its effect. It is as if the larva "walks" around the circle with one mouth brush, on the underside of the surface film. Movements of the two brushes remain synchronous. Rotation may be in either direction. Sometimes the head and thorax are turned towards the direction of rotation. Rotation is then usually faster.

The following figures were obtained for the frequency of brush movement, rates of rotation and forward movement for *A. communis* (averages of 4 readings). Giles (1902, p. 129) cites Nuttall as giving a frequency of 3 cycles/sec. for this movement in *Anopheles.*

Stimuli which evoke diving: To obtain a better knowledge of the extent of wriggling activity under natural conditions, the stimuli required to evoke diving were investigated. The effect of ground movements in muskeg areas on mosquito larvae has already been reported (Hocking *et al.,* 1950). A further study of this was

TABLE 1. The frequency of mouth brush movement and rates of rotation and progression. *Aedes communis* larvae

	Mouth brush frequency, cycles/sec.	Rotation, rev./min.	Speed, cm./sec
1st instar	4.2	4	0.21
2nd instar	5.3	3.2	0.28

made, and it was found that the larvae dived in response to ground movements only if these were of sufficient magnitude to result in visible surface ripples on the pools. When such ripples were produced by other means such as touching the surface with a stick or dropping in a very small stone, larvae and pupae dived as the circular ripple reached them. Almost all larvae returned to the surface within one minute.

Diving could also be evoked by visual stimuli. When opaque objects of various widths were moved parallel to the surface of the pool, larvae would dive as the object approached them. This was evidently not a shadow effect; the response was the same under sunny and overcast conditions. If the object were moved very rapidly, however, there was no response. The limiting distance above the water surface at which a response could be obtained with a given object depended on its width. By measuring these widths and distances, it was found that 2nd and 3rd instar larvae would respond only if the angle subtended by the object at the heads of the larvae, were greater than from 17° 30′ to 21° (average 19° 15′). A few observations were made on 4th instar larvae and pupae, which would respond at angles down to about 10°. This suggests that objects subtending smaller angles than these could not be resolved by the larval eyes, i.e., that the visual acuity of 2nd and 3rd instar larvae is about 0.00087, that of 4th instar larvae and pupae, about 0.0017. Hecht and Wolf (1929) recorded a maximum visual acuity of 0.017 for *Apis* and Hecht and Wald (1934) recorded 0.0018 for Drosophila (man 2.0–2.5). Thomas (1950) has reported that water vibrations and changes in light intensity are the stimuli which evoke diving in *Culex fatigans,* but found a decreased response in older larvae. Gordon (in Bates, 1949) found the larvae of *Anopheles darlingi* sensitive to a decrease in light intensity, but not to an increase.

Under natural circumstances in the north, these stimuli required for diving and wriggling activity are seldom provided. Rainfall, wind blown debris landing on the surface of a pool, and the visits of larger animals are perhaps the commonest events providing them. Larvae have been seen to dive in response to a bird flying very low over the pool. Their reactions to rain might well be studied. Perhaps the excessive demand for both larval and pupal wriggling in laboratory rearing, which is presumably largely responsible for their unfounded reputation for continuous activity, is also a major cause of mortality in the laboratory.

Summary: Observations on the natural activities of the larvae of *Aedes spp.* especially *A. communis* DeG. indicate that these are much less intense than has been commonly believed. Wriggling locomotion is rarely used in natural conditions; most movements are accomplished by means of the mouth brushes. The use of surface feeding with a circling movement, by these species, is described. An explanation of it is suggested. The mechanical and visual stimuli which evoke diving are described.

Acknowledgment: Some of these observations were made during the course of other studies while in the employ of the Medical and Veterinary Entomology Unit, Division of Entomology, Canada Department of Agriculture.

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STUDIES ON FINE SPRAY AND AEROSOL MACHINES FOR CONTROL OF ADULT MOSQUITOES [1]

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During 1951 and 1952 a comparative study was made of 5 machines for their ability to control infestations of adult *Aedes* mosquitoes about camps in Canadian woodland. They comprised the Microsol generator (Wilson *et al.*, 1949), the Husman sprayer,[4] a recent modification of the Besler generator (Brescia, 1946; Wilson *et al.*, 1949), the TIFA machine (Dickinson *et al.*, 1948; Horsfall, 1950; Peterson, 1952), and the Dyna-Fog generator (McDuffie *et al.*, 1950; Yeomans, 1950).

Determinations were made of the droplet spectra produced with oil solutions of DDT emitted at various rates; the droplet spectra at various distances downwind; the portions of the clouds that were deposited on the ground; the amount of DDT that reached various distances downwind both in the open and in the woods; and the percentage reduction in landing rates of *Aedes* mosquitoes obtained in woodland for distances up to 400 yd. downwind.

MATERIALS: The following 5 machines were tested: 1. The Microsol Mechanical Aerosol Generator, Agricultural Unit Model 403, Silver Creek Precision Corporation, Silver Creek, N. Y. (Fig. 1). The insecticide is mechanically atomized by being thrown off the periphery of a sheaf of twenty-one 8.5-in. discs rotating at 8125 to 9750 r.p.m. Power is supplied by a 7½-h.p. Wisconsin engine, with a gasoline consumption of 0.6 g.p.h. at 3000 r.p.m. The weight of the complete unit is 442 lb. empty.

2. The Husman Pneumatic Fine-atomizing Sprayer, made by C. N. Husman, U. S. Bureau of Entomology, Orlando, Fla. (Fig. 2). The insecticide is atom-

[1] Contribution No. 3052, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada. The results herein reported were obtained by the Division of Entomology in a program of studies on the biology and control of biting flies being carried out on behalf of the Defence Research Board and with the co-operation of that organization and other agencies.

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[3] Assistant Entomologist.

[4] See article by C. N. Husman, page 134, this issue of *Mosquito News*.—Ed. Note.

ized by air pressure at 8 to 15 p.s.i. supplied to a group of six 0.34-in. air-mix nozzles (No. 120-6-35-60 air combined with No. 4010 liquid in assembly No. 30, Spraying Systems, Chicago) by a rotary-vane compressor supplying 8.3 c.f.m. Power is supplied by a 1¼-h.p. Briggs and Stratton engine, with a gasoline consumption of 0.24 g.p.h. The weight of the complete unit is 125 lb. empty.

3. The Bes-Kil Aerosol Generator, Model A-120, Besler Corporation, Emeryville 8, California. The insecticide is atomized by steam at a temperature of 500 to 700° F. and a pressure of 100 to 150 p.s.i. The steam and the insecticide (pumped at 30 to 45 p.s.i. and not heated) meet at a single nozzle. Heat and power are supplied by a 1½-h.p. Lauson RSC-677 engine, with a gas consumption of 0.15 g.p.h. at 2800 r.p.m. The water for the steam is pumped at either 40 or 80 g.p.h., and the fuel oil for the burner to heat the steam is expended at 0.65 g.p.h. The weight of the complete unit is 920 lb. empty.

4. The TIFA, Todd Insecticidal Fog Applicator, Series 40-E, Todd Shipyards Corporation, New York, N. Y. (Fig. 3). The insecticide is injected into a fog-head through which hot air is blown at 1000° F., and 150 c.f.m. The air-blower, fuel pump, and insecticide pump are all operated at 1300 r.p.m. by a 6½-h.p. Briggs and Stratton engine turning at 2460 r.p.m. and consuming gasoline at 1.8 g.p.h. The insecticide is pumped at a pressure of 25 to 30 p.s.i. The fuel for the burner is pumped, from a gasoline tank shared with the engine, at 13 g.p.h. and 50 to 70 p.s.i. The weight of the complete unit is 600 lb. empty.

5. The Dyna-Fog Jet Insecticidal Fog Generator, Dyna-Fog Corporation, Dayton Municipal Airport, Vandalia, Ohio (Fig. 4). The insecticide is injected into the exhaust of a pulse-jet engine producing 60 explosions per second and combusting gasoline at 2.5 g.p.h. It is dispensed from a separate 17-gallon tank by utilizing an air-push of 6 p.s.i. borrowed from the engine. The weight of the unit, exclusive of the insecticide tank, is 95 lb. empty.

Three DDT formulations were employed in the tests. The first was a 5 per cent solution in fuel oil (Shell Oil Co.) supplied to the Canadian Army in 1951 on special order; the solvent was reported as kerosene in the 1952 issue, but presumably little difference is involved. This formulation is standard for treating army camps in Canada with the TIFA machine; its viscosity is 38.7 SSU (Table 1). The third formulation tested was a 30 per cent concentrate of DDT in a methylated aromatic solvent (probably unrefined polyalkylnaphthalenes) with a viscosity of 44.6 SSU. The second formulation was a 5 per cent solution made by diluting 1 part of the concentrate with 5 parts of Sovacide F (Socony-Vacuum Oil Co.). This was used because its low flash-point was suitable for the high temperatures generated by the Dyna-Fog and TIFA machines. All liquid volumes are quoted in this paper as imperial gallons (1 imp. gal.=1.2 U. S. gal.).

METHODS: The Microsol generator was mounted on the back of a 15-cwt. Dodge military truck, with the muzzle pointing backwards and upwards at an angle of 20° with the horizontal. The Husman sprayer was operated with the nozzle assembly held at breast height and directed downwind. The Bes-Kil generator was towed by a jeep; its single nozzle is 4 ft. above the ground, and it was directed downwind. The TIFA machine was mounted in the back of a 15-cwt. truck, with the fog-head held horizontal and pointed downwind. The Dyna-Fog generator was mounted on boards placed across the back of a jeep; when stationary it was supported on a platform 24 inches above the ground.

The droplet sizes of the sprays and aerosols were assessed by drawing air samples through cascade impactors (Casella) at 17.5 liters per minute (Fig. 5). Evacuated drums of 25 gal. capacity, with a valve set at the appropriate intake rate, were used for this purpose; a glass tap was also inserted to allow snap samples

to be taken close to the generator. The droplets were impacted on microscope slides coated with a thin film of a liquid silicone compound (G. E. Drifilm 9987). The coating was applied with cheesecloth, and it was thinned down by polishing it with at least 20 brisk strokes of a cheesecloth pad. Upon impact on this coating, the droplets produced lenses the diameters of which were approximately twice those of the droplets; the droplet/lens ratio, or spread factor, was determined by the focal length method (May, 1945) to be approximately 0.5 (Table 1), and

Fig. 1.—Microsol mechanical aerosol generator mounted in 15-cwt. truck, and elevated at 20° to the horizontal.

Fig. 2.—Husman pneumatic fine-atomizing sprayer. A (upper). Gasoline engine, compressor, and 5-gal. tank. B (lower). The air-mix nozzles, with air and liquid leads.

Fig. 3.—Todd insecticidal fog applicator (TIFA); note the clean break-away from the fog-head.

Fig. 4.—Dyna-Fog jet insecticidal fog generator; the unit with separate insecticide tank.

Fig. 5.—Cascade impactor, with glass tap and evacuated drum.

TABLE 1.—Physical constants of formulations employed

	Specific Gravity	Viscosity SSU at 70° F.	Refractive Index	Spread Factor
5% DDT in fuel oil (Shell)	0.845	38.7	1.46	0.52
5% DDT in Sovacide F	0.856	41.2	—	—
30% DDT in methylated aromatic	1.075	44.6	1.56	0.48

this factor was applied to assessments with all three oil formulations employed. The droplets were measured by means of a Patterson-Cawood ocular micrometer inserted into a compound microscope fitted with a mechanical stage. They were tallied according to size categories, and hence the total volume represented by the droplets in each size category could be computed. From these figures, the median diameter by mass (m.m.d.) was determined by the graphical method (Yeoman, 1949), with the modification that the upper limits of the categories, and not the mid-diameters, were used as ordinates.

Two other sampling methods were employed to confirm the cascade impactor results. Silicone-coated microscope slides were drawn by hand smartly downwards through the aerosol cloud. Slides coated with a glycerol-gelatin mixture (Hurtig and Perry, 1950) were exposed to catch the droplets in their spherical state, but attempts to use them in the cascade impactor were not successful, since the coatings either were too messy or became too hard. Initial samples of the cloud were taken 6 ft. from the generator, the distance being increased to 15 ft. with the Bes-Kil. The sampling height for the impactors was 4 ft.

The volume of material that fell out of the cloud on to the ground was measured by two methods. For short distances, lengths of a roll of paper towelling 10 in. wide were spread to form a continuous area; they were weighed before and after the machine emitted over it for a period of 1.5 seconds duration. For the longer distances, the fall-out was sampled by exposing 4-inch petri-dishes coated with silicone; the droplets deposited were measured and from them the total volumes were computed.

When the performance of the machines was sampled at distances exceeding 50 yards, they were towed along an emission line of 100 or 200 yd. at right angles to the wind direction, and the sampling points were located along a line running downwind of the mid-point of the emission line. This procedure was employed for the biological experiments in woodland as well as for the physical assessments. The speeds at which the machines were towed were between 1.2 and 3.4 m.p.h., being so adjusted that (with 5 per cent DDT solution) approximately 0.7 gal. containing 0.35 lb. of DDT were emitted for every 100 yd. of frontage. The times allotted each machine for covering 100 yd. were: Microsol, 2¼ min.; Husman, 2¾ min.; Bes-Kil, 1 min.; TIFA 2¼ min.; Dyna-Fog, 1½ min. When 30 per cent concentrate was emitted, the speeds were increased approximately 3 times.

The wind speeds at the time of application were measured by a thermopile Air-Meter (Hastings Instrument Co., Hampton, Va.). The temperature gradient, indicating whether there was upward convection (lapse) or air inversion, was measured by shielded thermocouples set up at heights of 1 m. and 2 m. and linked by a sensitive galvanometer.

The amounts of DDT reaching various distances downwind were sampled by means of 25-mesh copper screening cut into 9-in. squares, and held in a frame of ¾-in. angle iron at a height of 4 ft. and facing the oncoming cloud. For this method we are indebted to Dr. A. B. Hadaway, Colonial Insecticide Committee, who employed it in tsetse-fly control experiments in East Africa. The deposits

were washed off the screens by immersing them in 120 cc. of acetone in a medical instrument dish, and the DDT was determined by the Schechter-Haller method (Schechter *et al.*, 1945) with the nitration period limited to 30 minutes. When an attempt was made to assess the filtering efficiency of the screens, by taking 3 of them together one behind the other, it was found that the deposit was evenly divided between them, and the total figure was equivalent to that obtained by exposing one alone.

Cascade impactors were not employed to obtain recoveries of DDT because the amount sampled was far too low to be detected even by the Schechter-Haller method. The total amount recovered in one impactor from the cloud produced by the TIFA at a distance of 50 or 100 yd. was determined, by adding up the volumes of all the droplets, to be between 1 and 10 million cubic microns, which would not contain more than 0.05 to 0.5 micrograms of DDT. However, when an experiment was performed in which 30 per cent concentrate was emitted in 2 passes of the machine and eight impactor samples were added together, the amount recovered was increased by a factor of 96, and the DDT thus obtained at 100 yd. was determined to be 98 micrograms. Similarly, 48 micrograms were recovered at 200 yd. and 58 micrograms at 400 yd. If these figures are recalculated to the basis of 0.35 lb. of DDT emitted per 100-yd. frontage, they become 9.0, 4.4, and 5.3 micrograms respectively for the sampling rate of 140 l. per min. (8 by 17.5). If these figures are compared with those shown in table 9 which were obtained with the screens that might be expected to sample at approximately 10,000 l. per min. (*i.e.*, in a 7-m.p.h. wind, 346 cu. ft. passed through the screens in 1 min.), it will be seen that the screens are only about one-sixth as efficient as the cascade impactors in recovering aerosol material.

The effect of the DDT sprays and aerosols in reducing the landing rates of adult *Aedes* mosquitoes was assessed in open second-growth jack pine stands and in dense mixed woods containing spruce and poplar, at Petawawa, Ontario. The species represented in the population were as follows, in order of their abundance: *Aedes sticticus* (Meig.), *A. canadensis* (Theo.), *A. stimulans* (Wlk.), *A. excrucians* (Wlk.), *A. fitchii* (F. & Y.), *A. intrudens* (Dyar), *A. trichurus* (Dyar), *A. punctor* (Kby.) and *Mansonia perturbans* (Wlk.). The population was assessed by a team of 4 or 5 men shortly before the application and within 1 hr. after it; they went into the area on a compass bearing and paced out the intervals of 100 yd. for the 4 sampling points. The landing rate was determined, after waiting at the point for 1 min., by the number of landings of mosquitoes on the front of the trousers between knees and waist.

RESULTS: The delivery rates and droplet sizes produced by these machines at their normal settings are shown in tables 2 to 6. The values shown for the droplet sizes in many cases represent the averages of several determinations. For each machine the droplet sizes, as represented by the mass median diameters, rise as the delivery rate increases. The droplet sizes are also larger, and the atomization less, as the viscosity increases; although the consequent decrease in emission rate may minimize this difference. The best basis for comparing machines is to consider their performance at the same emission rate throughout; approximately 20 gal. per hr. is the most usual and convenient figure.

With the Microsol generator (Table 2) fine sprays are produced whose droplets are considerably larger than aerosol size, and constitute a compact spectrum from which the smaller size-classes are entirely lacking (Fig. 6). Smaller droplet sizes are obtained at lower emission rates, but even when it is reduced to 4 g.p.h. the atomization fails to depart from that of a fine spray. The settings for emission rate on this machine are approximate, depending on the degree of opening of a

TABLE 2.—Microsol generator: delivery rates (imperial gallons per hour) and droplet sizes (median diameter by mass, in microns); 5 per cent DDT in fuel oil (Shell)

Adjustment Setting	Delivery Rate g.p.h.	Mass Median Diameter microns
3000 r.p.m., 1/16 open	4	71
3000 r.p.m., 1/8 open	19	90
2500 r.p.m., 1/8 open	18	134
2500 r.p.m., 1/4 open	40	258

½-in. cock valve with a semicircular dial crudely engraved.

With the Husman sprayer (Table 3), the output is within the fine spray class, with a small component (approximately 10 per cent of the volume) falling within the aerosol class below 20 microns diameter. The emission rate increases more steeply than the air pressure applied, but the droplet sizes do not show a very significant increase. This is presumably because the rise in emission of insecticide solution is almost compensated by a rise in the pressure of air supplied to atomize it. The droplet spectrum with this sprayer approximates a normal frequency curve, extending down to the finest sizes, but it is sufficiently asymmetrical to include droplets of rather larger size than normal (Fig. 6).

The Bes-Kil generator (Table 4) can emit material at rates that are more than double those of the other machines. Although it is an aerosol generator, much of the large volume emitted falls into quite large size-classes, and thus the mass median diameter values are high (Fig. 6). The spectrum does not follow a normal frequency curve, but is more in the form of a plateau with occasional peaks, so that as much as 40 per cent of the volume may fall in the aerosol size-class. Nevertheless, at least 60 per cent of the output of this machine is lost as far as aerosol application is concerned.

The emission rates obtained with the TIFA machine are shown in Table 5, along with the mass median diameters determined at setting 10. Further determinations were not made, since a more complete set of droplet size data has already been published (Peterson, 1952). The droplet spectrum with this machine approaches a normal frequency curve (Fig. 6), so that a mass median diameter of 17 microns involves only 30 per cent loss in droplets larger than 20 microns, and only 1 per cent in the screening smoke class below 3 microns. The spectrum given by 5 per cent DDT solution emitted at 19 g.p.h. by the TIFA machine represents a satisfactory aerosol cloud.

The data obtained from the Dyna-Fog generator are tabulated in Table 6. Here a large number of droplet size determinations were made, with cascade impactors as well as hand-drawn slides; but the variation between samples was so great that it is impossible to quote single average values for the mass median diameter. One characteristic of the spectrum (Fig. 6) is that a very large proportion of the volume falls in the very small size-classes; these screening-smoke droplets give the aerosol from the Dyna-Fog its spectacular appearance. There is also a component of larger droplets extending into quite high size-classes. These characteristics are also evident in figures previously quoted for this machine (Yeomans, 1950). When sampled at a distance of 2 yd., and particularly with 5 per cent DDT in fuel oil emitted at setting 4, the fine droplets of the aerosol are still in process of recondensing; the contents of the cascade impactor reek when it is opened, and a considerable volume of droplets of various sizes and shapes are deposited on the fourth (last) slide of that apparatus. On the other hand, when this cloud is sampled by means of hand-drawn slides, an unusually large proportion of the bigger droplets are picked up, and remarkably high mass median diameters are obtained. Only with 30 per cent concentrate emitted at setting 8 could apparently normal droplet spectra be obtained.

The droplet sizes from the different machines that reach various distances downwind over open terrain are tabulated in Table 7. With the Microsol generator, the finest droplets in the spectrum reached

TABLE 3.—Husman sprayer: delivery rates and droplet sizes

	5% DDT in Fuel Oil (Shell)		5% DDT in Sovacide F		30% DDT in Methylated Aromatic	
	g.p.h.	microns	g.p.h.	microns	g.p.h.	microns
8 p.s.i.	7	33	—	24	7	30
10 p.s.i.	12	42	—	68	11	65
12 p.s.i.	15	36	11	36	14	35
15 p.s.i.	21	40	17	98	18	70

TABLE 4.—Bes-Kil generator: delivery rates and droplet sizes

	5% DDT in Fuel Oil (Shell)		5% DDT in Sovacide F		30% DDT in Methylated Aromatic	
	g.p.h.	microns	g.p.h.	microns	g.p.h.	microns
500° F., setting 4	40	54	—	—	40	52
700° F., setting 4	40	26	—	26	40	52
500° F., setting 8	68	45	—	—	65	98
700° F., setting 8	68	102	—	90	68	82

TABLE 5.—TIFA: delivery rates and droplet sizes (for further data see Peterson, 1952)

	5% DDT in Fuel Oil (Shell)		30% DDT in Methylated Aromatic	
	g.p.h.	microns	g.p.h.	microns
Selector setting 10.2	19	17	17	26
Selector setting 11.5	24	—	20	—
Selector setting 15.6	39	—	31	—

TABLE 6.—Dyna-Fog generator: delivery rates and approximate droplet sizes.

	5% DDT in Fuel Oil (Shell) g.p.h.	5% DDT in Sovacide F g.p.h.	30% DDT in Methylated Aromatic g.p.h.	Range of m.m.d.'s for All 3 Formulations microns
Setting 4	18	13	13	1–5
Setting 6	28	21	20	3–30
Setting 8	32	32	27	10–50

as far as 100 yd. but no farther. These droplets are, of course, considerably larger than aerosol size, and they drifted for that distance because they were thrown out at an angle of 20° with the horizontal, by turbine-type vanes located behind the discs, to a maximum height of 8 ft.

With the Husman sprayer, a residuum of fine droplets succeeded in reaching distances up to 400 yd. From 200 to 400 yd. distant from the source, only the finest droplets are present in the cloud, regardless of the machine employed. At 100 yd., the recoveries from the Husman and Bes-Kil machines were of larger droplet size than that from a true aerosol generator such as the Dyna-Fog. But at 200 to 400 yd., the only droplets of the Bes-Kil's output to reach that distance were very small, which may have a bearing on the slight effect on mosquitoes.

The amounts of material emitted that

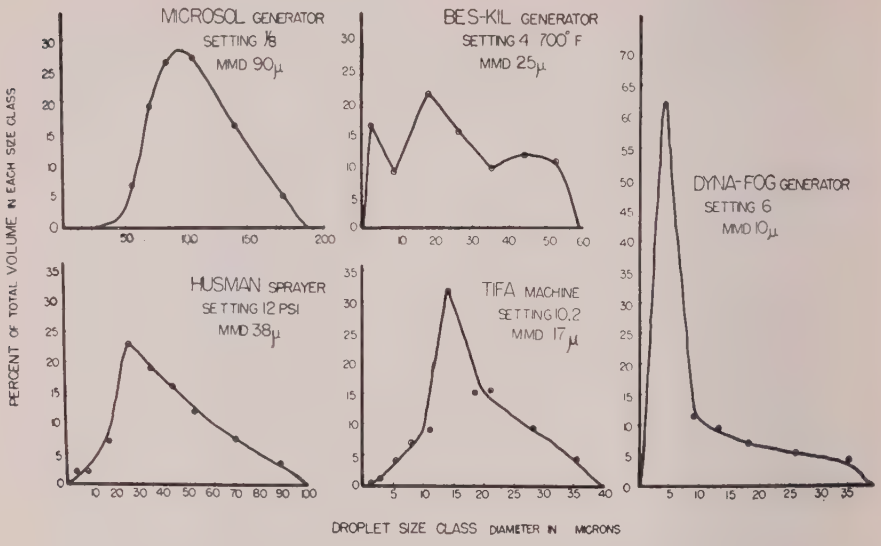

Fig. 6.—Droplet spectra obtained by the 5 machines with 5 per cent DDT in fuel oil.

fell out of the air-borne cloud and were deposited on the ground are shown in Table 8. The Microsol generator deposited all its material within a distance of 150 yards downwind, and only 30 per cent of the volume drifted farther than 50 yards. With the Husman sprayer, the bulk of the material remained air-borne for considerable distances. However, in a light wind a considerable proportion (at least 7 per cent) fell to the ground within 5 yd. of the nozzles. The ground recoveries determined for this and the following machines tested were considerably lower than the true figures; for example, the proportion of the output of the Husman sprayer at 12 p.s.i. that reached 300 yd. was certainly not as much as 90.6 per cent, as the figures in Table 8 appear to indicate.

With the Bes-Kil generator there was a significantly high ground contamina-

TABLE 7.—Mass median diameters, in microns, of airborne droplets at various distances; 5% DDT in fuel oil

Generator	Wind Speed m.p.h.	Distances Downwind from Source, in Yards					
		25	50	100	200	300	400
Microsol							
3000 r.p.m., 1/8 open	7	42	34	36	—	—	—
Husman							
10 p.s.i.	11	—	—	15.5	3.5	—	5.5
12 p.s.i.	1	—	—	6.2	4.4	—	—
Bes-Kil							
500° F., setting 4	9	—	—	5.0	2.7	1.9	1.3
700° F., setting 4	9	—	—	25	2.0	2.3	1.8
Dyna-Fog							
Setting 6	3	—	9.2	5.8	3.7	—	2.5

TABLE 8.—Percentages of total volume emitted that fell to the ground within the various distances downwind from the source; 5 per cent DDT in fuel oil

Generator	Wind Speed m.p.h.	Distances Downwind from Source, in Yards							
		5	10	25	50	100	150	200	300
Microsol									
3000 r.p.m., ⅛ open	4	6.4	18.3	42.1	70.8	97.2	100	100	100
Husman									
12 p.s.i.	1	6.98	7.17	7.18	7.19	Not determined			
10 p.s.i.	11	0.25	3.5	7.1	8.0	8.7	9.0	9.2	9.4
Bes-Kil									
500° F., setting 4	6	0.8	1.7	3.8	3.81	3.82	3.821	3.822	3.8227
700° F., setting 4	9	0.5	2.3	4.06	4.13	4.16	4.18	4.19	4.192
TIFA									
Setting 10.2	4	0.002	0.004	No further appreciable fall-out					
Dyna-Fog									
Setting 6	4	0.01	No further appreciable fall-out						
Setting 5	4	0.02	No further appreciable fall-out						

tion, which reached its maximum between 10 and 15 yd. away from the nozzle. On the other hand, the loss of air-borne material from the TIFA machine was very small. But it was sufficient to make the grass immediately in front of the fog-head reek immediately after the cloud had passed over it.

With the Dyna-Fog generator, there was a greater deposit immediately in front of the machine than with the TIFA, owing to the presence of a few larger droplets in the cloud. Although still negligible when 5 per cent DDT in fuel oil was used, the amount deposited in the first 5 yd. was between 0.25 and 0.6 per cent when the 5 per cent solution in Sovacide or the 30 per cent concentrate was emitted at setting 8. Evidently the insecticide solution is impacted on the inner walls of the emission pipe, runs down to the flange at the end, and is atomized there as coarse droplets. With the TIFA, on the other hand, an encircling blast of air in the fog-head carries the material clear out of the atomizing cup (Fig. 3).

The recoveries of DDT from the air-borne cloud are shown in Table 9 for passage over open terrain, and in Table 10 for passage through woodland. The woods had filtered out most of the output from the Husman sprayer by the time it

TABLE 9.—Recoveries of DDT, in micrograms, on 81-sq.-in. screens held at various distances downwind of emission over open terrain; 5 per cent DDT in fuel oil

Generator	Wind Speed m.p.h.	Distances Downwind from Source, in Yards*					
		25	50	100	200	300	400
Microsol	2–5	310	405	102	0	0	0
Husman	8	—	1165	85	41	41	48
Bes-Kil	8	—	339	178	152	144	140
TIFA	5–9	—	468	213	99	93	59
Dyna-Fog	5–9	—	113	72	54	44	50

* Results calculated on the basis of 0.35 lb. of DDT emitted per 100-yd. frontage. Average of 2 runs for Microsol, and of 3 runs each for TIFA and Dyna-Fog.

TABLE 10.—Recoveries of DDT, in micrograms, on 81-sq.-in. screens held at various distances downwind of emission through woodland; 5 per cent DDT in fuel oil

	Distances Downwind from Source, in Yards*					
Generator	25	50	100	200	300	400
Microsol	37	51	85	0	0	0
Husman	—	357	55	10	0	0
Bes-Kil	—	—	33	21	2	0
TIFA	—	—	72	82	59	43
Dyna-Fog	—	—	48	39	20	15

* Results calculated on the basis of 0.35 lb. of DDT emitted per 100-yd. frontage. Average of 2 runs for Microsol, TIFA, and Dyna-Fog.

had reached a distance of 300 yd. Broad-leaved trees close to this sprayer intercepted so much material that the foliage glistened with it. The cloud from the Bes-Kil did not carry much DDT beyond 200 yd. into woodland (Table 10). On the other hand, with the TIFA and Dyna-Fog significant amounts of DDT were still air-borne after the cloud had travelled as much as 400 yd. through woods. Table 9 shows that the decrease in air-borne material was least abrupt in the case of the Dyna-Fog, which gives the finest droplet spectrum.

Applications could be made to woods from roads running through them provided there was a sufficient wind speed to move the cloud off the road; the machines were driven as close to the boundary of the trees as possible. Under conditions of strong upward convection, it was impossible for the cloud to enter woodland unless the wind speed in the open exceeded 10 to 15 m.p.h., but in the evening as the temperature gradient approached zero it was possible to treat woodland when the free wind speed was only 4 m.p.h. Where the road had a cleared border on the upwind edge the task became easier, but when it was enclosed between woods the wind speed on the road might be less than one-tenth of that in the open. It was possible on many occasions to treat woodland satisfactorily in the middle of the day.

The reductions in landing rates effected by these machines emitting into woodland are shown in Table 11. These reductions do not necessarily imply that the mosquitoes were killed. The amounts of DDT applied in these tests approximated 0.35 lb. per 100 yd. of frontage, equivalent to a dosage of 0.04 lb. per acre if the distance between application is 440 yd. This level of application effected a partial reduction in landing rate and thus furnished a convenient basis of comparison for the performances of the several machines; for operational use in Canadian woodland this dosage could be considerably increased, for example, to 0.10 lb. per acre. There was no significant difference in biological effect whether a given amount of DDT was applied in 5 per cent solution or in the 30 per cent concentrate (see last line, Table 11).

The Microsol generator was tested on two occasions, when the wind speed was 6 m.p.h. and strong upward convection prevailed, circumstances that should increase the distance travelled by the spray. However, no reduction in the mosquito landing rate could be detected beyond 250 yd. downwind.

With the Husman sprayer, good results were obtained under conditions of considerable lapse, the effect extending for 400 yd. through open pine woods. But when the spray was emitted through dense mixed woods, the biological effect was mediocre at 100 yd. and insignificant beyond that. In the two tests performed with the Bes-Kil generator, only slight reduction of mosquitoes was obtained at the greater distances in dense mixed woods.

TABLE 11.—Biological effectiveness of 5 machines against *Aedes* mosquitoes in eastern Canadian woodland

Machine employed	lb. DDT emitted per 100 yd.	Percentage Reduction in Landing Rate 100x	200x	300x	400x	Average	Conditions
5% DDT in Fuel Oil (Shell)							
Microsol*	0.28	77	71	0	0	37	Strong lapse, strong wind
Husman	0.27	48	33	24	0	26	Dense
Bes-Kil	0.35	73	41	32	10	39	mixed woods
Husman	0.38	94	93	71	61	80	Considerable lapse,
Dyna-Fog	0.44	98	62	54	48	66	open pine woods
Bes-Kil	0.33	87	21	0	0	27	Dense
Dyna-Fog	0.45	97	92	87	69	89	mixed woods
TIFA	0.36	89	69	77	68	74	Open
Dyna-Fog	0.29	97	82	83	87	88	poplar woods
TIFA	0.38	97	96	90	75	88	Open
Dyna-Fog	0.35	95	90	89	72	87	poplar woods
30% DDT in Methylated Aromatic Oil							
Husman	0.70	61	14	27	32	34	Dense
Dyna-Fog	0.61	100	97	82	81	90	mixed woods
TIFA	0.35	74	98	82	28	72	Dense
Dyna-Fog	0.42	100	80	90	96	91	pine woods
TIFA	0.36	88	98	61	62	74	Dense
Dyna-Fog	0.42	94	90	78	67	83	poplar woods
Comparison of 5% DDT with 30% DDT							
TIFA, 5%	0.35	100	100	91	100	96	Open
TIFA, 30%	0.28	100	94	85	70	90	pine woods

* Percentage reductions at 25, 50, 75, 125, 150 and 250 yd. were 100, 85, 79, 78, 82 and 58 respectively.

The TIFA and the Dyna-Fog generator gave very much better results than the other three machines, especially at the greater distances. Nevertheless, the reductions in landing-rate were significantly lower at 300 and 400 yd. than in the first 200 yd. downwind of the generator (Table 11). There is a tendency for the Dyna-Fog to obtain higher reductions in landing rate than the TIFA, particularly when the woods are dense; the finer atomization with the jet generator presumably confers an advantage here. However, under conditions of high lapse rate over open woods, the situation is reversed.

DISCUSSION: It is clear from the results that the only two machines suitable for treatment of *Aedes* adults with aerosols in woodland are the TIFA and the Dyna-Fog. In these experiments, the Dyna-Fog gave slightly better results than the TIFA. In tests performed in Alaska (McDuffie *et al.*, 1950) the TIFA proved slightly more effective than the Dyna-Fog, when the terrain was more open with scattered spruce.

The TIFA, although a heavy machine, has a number of excellent features. It produces aerosols of comparatively uniform droplet size, the spectrum approximating a narrow probability curve. The droplet size may be modified by adjusting the emission rate while keeping the air-blast temperature constant, or by adjusting the temperature while keeping the emission constant (Peterson, 1952). The gasoline engine is reliable and runs smoothly, so that the machine may drain

one 45-gal. drum of insecticide after another, and be safely left unattended for long periods. The TIFA machine may be conveniently bolted on a 15-cwt. truck.

The Dyna-Fog generator is light in weight and approximates the TIFA in biological effectiveness, despite an uneven droplet spectrum. The 17-gal. drum with which it is provided allows 45 min. of continuous emission before the machine is shut down for refill. The rate of gasoline consumption is higher than with the TIFA, and the presence of water in the gasoline is more liable to cause stoppage. When the jet stops, the insecticide solution in oil must be quickly turned off, because it ignites at the end of the muzzle. The noise level of the Dyna-Fog generator is high and sharp. Being a portable generator, it is not provided with hold-fast attachments for mounting in a vehicle. The Dyna-Fog is a precision machine that is simple in principle, but it requires skill and coolness in the operator.

The Bes-Kil gave comparatively low results against mosquitoes in woodland in spite of its higher emission rate. It appears that a large fraction of the fog is removed as impingement of larger droplets on foliage (in fact, this machine is used for just that purpose in orchard spraying). Much of the volume that remains air-borne is in extremely fine droplets too small to be very effective against mosquitoes. The heavier weight of this machine, coupled with its large appetite for water, also renders it unsuitable. However, it should be valuable for treating large expanses of open marsh with a few good roads traversing them.

The Husman sprayer shows remarkable versatility for a machine that is so light and simple in construction. Its rate of output is comparable to those of much heavier machines, and because of this large volume there is a sufficient amount of the smaller droplets available to affect mosquitoes at a distance. In open country and under conditions of high air turbulence this little machine can be very effective. If the present nozzles are replaced with designs that prevent the formation of the larger droplets in the spectrum, the Husman sprayer may be expected to provide a simple and effective means of controlling mosquitoes in any situation.

The Microsol generator is not adapted for control of adult mosquitoes on an area basis. However, it has possibilities for larval control; in these tests it produced 75 per cent mortality of *Aedes* larvae in a sheltered woodland pool 350 ft. away from the machine. Although similar results could be obtained with other mist-blowers (Turbine sprayer, Lawrence sprayer), the comparative lightness and compactness of the Microsol generator are an advantage.

In experiments performed with the TIFA in Alaska, 20 and 10 per cent DDT solutions were dispersed in open spruce forest at 5 U. S. gal. per mile of front (McDuffie *et al.*, 1950), the expenditures thus being respectively 0.47 and 0.23 lb. DDT per 100 yd. At 0.47 lb. per 100 yd., the reduction in landing rate in the first 200 yd. downwind was 99 per cent 3 hr. after application, and 98 per cent 12 hr. after application. At 0.23 lb. per 100 yd., the reduction 12 hr. after application was 80 per cent for the first 200 yd. downwind, and 33 per cent for the next 100 yd. In experiments in the Yukon Territory against *Aedes punctor* and associated species (Peterson, 1952) application of 5 per cent DDT solutions at 0.24 lb. per 100 yd. (8.05 lb. per 10,000 ft. quoted) in open pine forest gave complete reduction for distances of 100 to 800 yd. With the same expenditures in southern Ontario against *A. intrudens* and associated species in a forest of pine, willow, and poplar, complete reduction was obtained only in the first 50 to 100 yd. Experiments in Illinois with 5 per cent DDT solution (Horsfall, 1950) established that expenditures equivalent to 0.7 lb. per 100 yd. gave 80 per cent mortality of *Culex pipiens* exposed in cages 50 yd. downwind. Experiments in California (Dickinson, Merrit and Hough, 1948) gave complete

control of *A. nigromaculis* for 440 yd. downwind at an expenditure of 0.47 lb. per 100 yd. (20 U. S. gal. of 5 per cent DDT per mile of front); their entire program against adults involved an average expenditure of 0.048 lb. of DDT per acre treated. The TIFA manufacturer recommends applying 5 per cent solution from a vehicle moving at 2 m.p.h., which, with the machine at setting 10, gives an expenditure of 0.25 lb. per 100 yd. (Todd, 1951); if parallel runs are made every 250 yd., the dosage is 0.05 lb. per acre, equivalent to the figure of 1 U. S. pint of 5 per cent DDT solution per acre quoted. Operations in Illinois, presumably following this method, obtained 97 per cent mortality at 100 yd., 95 at 200 yd., 92 at 300 yd., and 72 at 400 yd. (Todd, 1951). In the experiments described in this paper with *Aedes sticticus* and associated species in Ontario, the average figures for reductions in landing rate for an average expenditure of 0.36 lb. per 100 yd. over woodland are: 89 per cent for 200 yd., 77 per cent for 300 yd., and 58 per cent for 400 yd. from the machine.

The Besler aerosol generator, as the No. 1 inventor's modification model of Hochberg and LaMer, has been assessed for control of adults of *Aedes sollicitans, A. taeniorhynchus* and *Anopheles quadrimaculatus* in Florida (Brescia, 1946). When 5 per cent DDT emulsion was emitted at 1.9 lb. per 100 yd. (15 U. S. gal. per 1000 ft.), effective control was obtained for 1800 yd. in the open and 300 yd. in forest. When a further modified Besler (CWS Disperser E-15) was tested in Alaska with a 5 per cent solution at an expenditure of 1.5 lb. per 100 yd. (Wilson, Applewhite and Redlinger, 1949), there was considerable reduction of *Aedes* mosquitoes but the landing rate returned to its former level 24 hr. later. In the experiments described in this paper, with the Bes-Kil model which differs from the Besler generators previously tested in that the insecticide does not pass through the steam coils, the average reductions for an expenditure of 0.34 lb. per 100 yd. over woodland are 80 per cent at 100 yd., 27 per cent at 200 yd. and negligible reduction beyond that distance.

The Microsol (Hession) generator has been tested in Alaska at approximate expenditures of 1 to 5 lb. of DDT per 100 yd. of frontage; the treated area showed no reduction of mosquitoes when examined the following day (Wilson, Applewhite and Redlinger, 1949). The two experiments performed in Ontario woodland reported in this paper gave, with an expenditure of 0.3 lb. per 100 yd., 85 per cent reduction at 50 yd., 77 per cent at 100 yd., 71 per cent at 200 yd., 58 per cent at 250 yd., and no reduction beyond that distance. These results make it clear why the Alaska workers did not observe any reduction in the vast open areas into which they were emitting insecticide with this short-range machine.

The Dyna-Fog generator has been tested in Alaska (McDuffie *et al.,* 1950) in open spruce forest. With 20 per cent DDT solution applied at 0.47 lb. per 100 yd., the reduction in the first 200 yd. downwind was 95 per cent 3 hr. after application, falling to 63 per cent 12 hr. after application. With 10 per cent solution applied at 0.23 lb. per 100 yd. the reduction in the first 200 yd. downwind was 99 per cent 3 hr. later; 12 hr. after the application the average reduction in the first 200 yd. was 84 per cent, and in the next 100 yd. downwind it was only 24 per cent. In the experiments reported here, the immediate average reductions after applications that averaged 0.42 lb. per 100 yd. were 99 per cent at 100 yd., 85 per cent at 200 yd., 80 per cent at 300 yd. and 74 per cent at 400 yd. downwind.

The recoveries of DDT by the Schechter-Haller method allow comparisons to be made between the percentage reduction in the landing rate of mosquitoes and the amount of DDT reaching various distances downwind. For example, at a distance of 400 yd. downwind of the TIFA machine, in woodland, the average reduction was 58 per cent, and the recovery of DDT at that distance was 43 micrograms for the 81-sq.-in. screen, equivalent to 77 micrograms per sq. ft.

With the Dyna-Fog, at a distance of 400 yd., an average reduction of 74 per cent in landing rate was paralleled by a DDT recovery of 27 micrograms per sq. ft. These figures may be compared with those obtained for the actual mortality of *A. aegypti* exposed to an aerosol of oil containing 5.8 per cent DDT moving at 2 m.p.h. through a wind tunnel; these were 15 per cent for a passage of 175 micrograms of DDT per sq. ft., and 49 per cent for a passage of 5900 micrograms per sq. ft.

The results of the present investigation may also be considered with reference to the *Ct* (concentration *C* in mgm. per cu. m. of air, multiplied by time of exposure *t* in minutes) of the DDT in the aerosol expressed in mg.-min./m^3. With the wind moving through the 81-sq.-in. screens at 1 m.p.h., a median figure for the conditions in woodland, the volume of air sampled is 1.4 cu. m. per min. If it is assumed that the aerosol cloud took 1 min. to complete its passage through this point, the *Ct* is $0.043 \div 1.4 = 0.03$ mg.-min./m^3. This figure would be identical if, instead, a time of passage of 2 min. was assumed. Similarly, the *Ct* for the DDT in the aerosol for the Dyna-Fog at 400 yd. is 0.01 mg.-min./m^3. On the other hand, the *Ct* required to produce mortality of 50 per cent *A. aegypti* exposed to a settling aerosol containing 8 per cent DDT in oil (LaMer *et al.*, 1947) was as much as 140 mg.-min./m^3.

In interpreting these results it should be remembered that the recoveries obtained by the screens were probably low, and may be as little as one-sixth of those obtainable by a direct air-trapping method such as by the cascade impactor. But even then there still remains a large discrepancy between the dosage sufficient to give a reduction in landing rate in the field and that required to produce mortality as indicated by laboratory experiments. In fact, the workers in Alaska observed that after passage of a DDT aerosol cloud the mosquitoes would gradually reappear about their feet, and after some hours would reach higher levels. Further investigation is needed on this point. Certainly the aerosols used in this investigation had no discernible effect on flying anthomyiids, tachinids, tabanids, tipulids, Neuroptera, Odonata, and Hymenoptera.

SUMMARY: Assessments were made of the performance of 5 machines in producing aerosols from oil solutions of DDT for control of adult *Aedes* mosquitoes. When 5 per cent DDT in kerosene was emitted at approximately 20 g.p.h., the mass median diameter of the droplet spectrum produced by the Microsol generator was 90 microns; by the Husman sprayer, 40 microns; by the TIFA, 17 microns; and by the Dyna-Fog generator, approximately 5 microns. With the Bes-Kil generator the minimum emission rate was 40 g.p.h. and the resulting mass median diameter was 30 microns.

The Microsol generator is therefore not an aerosol machine and its effectiveness did not extend beyond 200 yd. downwind. The Husman sprayer was effective for distances up to 400 yd. in open woodland but not in dense woods. The Bes-Kil generator gave poor results in dense woods despite its high emission rate of aerosol droplets. Both the TIFA machine and the Dyna-Fog were effective in reducing the landing rates of *Aedes* mosquitoes at distances up to 400 yd. through dense woods.

At average dosages of 0.35 lb. of DDT emitted per 100 yd. of frontage, the average percentage reductions for the TIFA and the Dyna-Fog were, respectively, 89 and 91 at 200 yd., 77 and 80 at 300 yd., and 58 and 74 at 400 yd. downwind. Of the 5 machines only these two gave significant dosages of DDT at distances of 300 and 400 yd. in woodland.

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MOSQUITO BREEDING IN ALASKAN SALT MARSHES, WITH ESPECIAL REFERENCE TO *AËDES PUNCTODES* DYAR

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In subarctic and temperate Alaska, settlements, salt marshes, and mosquitoes tend to occur wherever there is flat land at sea level. The mosquitoes, so far as known, are chiefly species of *Aëdes* which breed in fresh water also. What the significance of these saline waters for mosquito control may be is a matter of uncertainty. In fact, few observations of mosquito larvae in subarctic salt marshes are recorded. Jenkins (1948) and Dr. Alan Stone (unpublished) of the Alaska Insect Project report *Aëdes punctor, communis* and *flavescens* larvae in waters brackish to the taste. The former two species, they note, have shortened gills in the saline habitats, and among the full-grown *"punctor"* larvae, atypical open anal saddles are frequent. In temperate Scandinavia, Natvig (1948) reports *Aëdes communis* from water of about 0.07% NaCl content. In North German coastal pools, *Aëdes excrucians* is known to tolerate slightly brackish conditions (Martini, cited in Natvig, 1948).

The present preliminary study, reporting observations made during three seasons in two sharply different zoogeographical regions of Alaska lying about a thousand miles apart, indicates that a single species, *Aëdes punctodes* Dyar, is the predominant mosquito larva of the salt-marsh habitats of both regions. The study provides a preliminary list of the other brackish species, and describes some typical larval habitats of these mosquitoes with reference to salinity and vegetation. Salinity tolerance of two of the principal larvae indicated by the field survey was checked experimentally in the laboratory. Unfortunately, identification of an Alaskan salt-marsh mosquito problem with *Aëdes punctodes,* a rather distinct member of the perplexing *punctor* complex, does not make biological data available to the practical man. Knight (1951) in proposing recognition of *punctodes* Dyar states that "no specific notes are available on its biology." Thus this paper introduces the larval ecology of *Aëdes punctodes.*

PROCEDURE. Mosquito larvae, larger plants, periphyton, and salinity samples were collected at weekly intervals during May and June 1950, in 23 breeding areas of the Upper Cook Inlet marshes. The areas were selected and provisionally classified according to dominant larger plants. The beds of these plants corresponded, in general, to a certain salinity range though zonation was sometimes indefinite. The temperature of the surface water and the air, pH, color, and turbidity were recorded routinely. Occasional notes recorded the extent of the highest tides, changing light (shade) conditions, invasions of fish predators, etc. Salinities and larvae were determined in the laboratory. Experiments on larval salinity tolerance using mixtures of fresh and sea water proved impractical in natural pothole habitats. Therefore similar experiments were carried out in stender dishes in the laboratory. Salinities were determined to within about one part per hundred thousand by duplicate titrations with a standard solution of silver nitrate for chlorides, the end-point being indicated colorimetrically by potassium dichromate solution. The results have been expressed as parts per hundred thousand (ppht.) of chlorine so that even the lowest salinities are whole numbers. The computation of salinity, as defined by oceanographers, and the corresponding percentage of sea water can be made from these data (Muirhead-Thomson, 1951, p. 182), but the calculations with long decimals are tedious and the benefits dubious to mosquito workers.

Identification of larvae of the *punctor*

complex is subject to a certain error pointed out by Knight (1951) whose key was used for separating *punctor* and *punctodes*. He says: "an occasional *punctor* larva is found in the Fairbanks-Anchorage area which intergrades with the larvae of *punctodes*." Since about 90% of the larvae identified in this study belonged to these two forms or species, it is regrettable that there has not yet been sufficient time for the rearing in isolation of series of the two from the different types of salt-marsh habitats, for in this way the percentage of each species could be determined more accurately by habitat. However, since *punctor* predominated in the fresher habitats, *punctodes* in the more salt, and because specimens studied by Knight included associated larval exuviae and male genitalia from some of the marshes of this study, it was possible to make valid general conclusions from larval identifications.

Salt Marshes and Larval Habitats. The ecological differences between these Alaskan salt marshes and those of warmer coasts are obviously considerable. In the Cook Inlet marshes, the larger plants—those excellent visible indicators of invisible salinity, tidal, and other differences—are dominated by a relatively small number of ubiquitous, tolerant species which presumably reflect the rigorous selection exercised by low temperatures as well as salt. The same may be said for the mosquitoes whose larval habitats are conveniently named after the weed beds where they are found. There are, nonetheless, in addition to the tolerant, primarily fresh-water plants which are adapted to withstand lower salinities, some true halophytes such as *Salicornia herbacea* L. But these salt plants are few and inconspicuous, and with reference even to the strictly coastal succulents, e.g., *Chrysanthemum arcticum* L., a beautiful daisy, they seem to represent northern as much as saline forms. And all of the mosquitoes, so far as known, belong to fresh-water species which are either quite resistant to salt, or, in the relatively few thousands of years since the glaciers retreated from the water front, have acquired a tolerance for salinity, possibly only in parts of their vast northern ranges. Farther south along the coasts of Washington and Oregon only *Aëdes dorsalis* breeds in salt marshes (Stage *et al.*, 1952). Absence of competitive, obligatory salt-marsh mosquitoes may have been a factor which favored their invasion of salt marshes.

In the regions studied, the titrations proved that five more or less conspicuous vegetation zones are correlated with certain salinity ranges. The larval identifications further proved that the mosquito habitats within each zone differed consistently from those of other zones and that stations of the same habitat type harbored similar assemblages of larvae in the different marshes. This is the basis for the classification given, while the reason for its usefulness is the ease with which anyone may use it. Unfortunately, nevertheless, the types of habitat are composite. Preliminary study of the microbiotas, especially algae which include indicator organisms more sensitive than the larger plants or mosquitoes, show that the *Carex* and *Myrica* types should be subdivided. These three types support different microbiotas to a degree which is not permissible for mosquito habitats of the same type. At this early stage of the study and for the use of mosquito workers who must make field surveys with the naked eye rather than the compound microscope the simpler, though imperfect, preliminary classification which follows is preferable:

Types of Brackish Mosquito Habitats of the Upper Cook Inlet: (1) *Triglochin* Type: Salinity, Range, 330.5–844.4, Average 631.4; Dominant Plant, *Triglochin maritima* L.; pH, Range, 6.5–8.6, Average, 7.46; Water Color, none to brown; Light Condition, open; Surface Temperature, warm, Index,* 14.4 degrees C.; Other Conspicuous or Abundant Plants, *Plantago maritima* L. *juncoides* (Lam.) Hult., *Potentilla Anserina* L., *Scirpus validus* Vahl., *Glaux maritima* L., *Salicornia herbacea* L.

(2) Brackish *Carex* Type: Salinity, Range, 192–700.4, Average, 397.4; Domi-

* Averages, June 5–8.

nant Plant, *Carex lyngbyei* Hornem.; pH, Range, 5.8–8.1, Average, 6.75; Water Color, none-straw; Light Condition, partly shaded; Surface Temperature, medium, Index, 11.8 degrees C.; Other Plants, *Potentilla Anserina, Eleocharis kamschatica* (C.A. Mey.) Kom., *Chrysanthemum arcticum* L., *Plantago maritima juncoides, Triglochin maritima, Iris setosa* Pall., *Scripus validus.*

(3) Fresh-water *Carex* Type: Salinity, Range, 5.1–91.9, Average 45.4; Dominant Plant, *Carex lyngbyei;* pH, Range, 6.3–7.0, Average, 6.62; Water Color, none-pale brown; Light Condition, partly shaded; Surface Temperature, medium, Index, 13.3 degrees C.; Other Plants, *Myrica Gale* L., *Scirpus validus, Potamogeton filiformis* Pers., *Potentilla Anserina, Salix* prob. *nana, Rumex fenestratus* Greene.

(4) *Myrica* Type: Salinity, Range, 8.0–57.5, Average, 30.9; Dominant Plant, *Myrica Gale;* pH Range, 6.2–7.0, Average 6.62; Water Color, none-brown; Light Condition, shaded; Surface Temperature, cold, Index, 8.2 degrees C.; Other Plants, *Calamagrostis canadensis* (Michx.) Beauv., *Iris setosa, Salix* prob. *nana, Rumex fenestratus.*

(5) Seepage Type: Salinity, Range, 23.5–65, Average, 38.6; Dominant Plant, uncertain, varies, *Caltha palustris asarifolia* (DC) Hult.; pH, Range, 6.8–7.6, Average, 7.05; Water Color, straw; Light Condition, open; Surface Temperature, warm, Index, 15 degrees C.; Other Plants, *Equisetum arvense* L., *Rumex fenestratus, Iris setosa, Dodecatheon macrocarpum* (Gray) Knuth.

MOSQUITOES. General. Twelve, or about half of all the species of mosquitoes known to occur in Alaska, were found breeding in Upper Cook Inlet saline marshes, viz.: *Aëdes punctodes, punctor, hexodontus, impiger, communis, excrucians, pionips, flavescens, cinereus, Culiseta impatiens, alaskaënsis,* and *morsitans.* The first two are of overwhelmingly greater importance than the others, however, and as a result of their abundance the data for these two are especially instructive. For instance, their distribution with reference to types of habitats in the salt marshes is illustrated by analysis of 55 collections of large larvae. In the collections from the most saline waters (*Triglochin* Type), *punctodes* predominated; in those from the freshest waters (*Myrica* Type), *punctor* predominated; and in the intermediate salinities, intermediate mixtures of the two species occurred. The breakdown by percentages of these collections with (1) *punctodes* numerically dominant, (2) the two species about equally numerous and (3) *punctor* most numerous, by habitat type follows:

(A) *Triglochin* Type—91% *punctodes,* 9% subequal, 0% *punctor;* and note that 90% of the predominant *punctodes* class had no *punctor* larvae.

(B) Brackish *Carex* Type—76% *punctodes,* 12% subequal, 12% *punctor;*

(C) Fresh *Carex* Type—46% *punctodes,* 16% subequal, 38% *punctor;*

(D) *Myrica* Type—26% *punctodes,* 21% subequal, 53% *punctor;* and note that 41% of the *punctor* class had no *punctodes,* although most of these same stations yielded *punctodes* on other dates.

The other ten species of mosquitoes differ obviously in both larval salinity tolerance and in practical importance (adult abundance); but more data are needed to rule out variables affecting both. Yet it is reasonable to propose tentatively that four other *Aëdes,* viz. *impiger, excrucians, flavescens,* and *communis* are the species of secondary importance in both regards. *Impiger* and *communis* are apparently less salt-tolerant, but they occur more frequently than the other two, especially in *Myrica* potholes. *Excrucians* and *flavescens* seem to be definitely salt-tolerant (both occurring in 500–800 ppht.), but they were relatively less common.

Reduction of gills. As appears to be universally true for salt-marsh mosquitoes, on the whole the Alaskan saline larvae have smaller gills than fresh-water species. (How this relates to a water-regulatory function need not concern us here.) It is

especially noteworthy that these particular northern species which "spill over" from fresh-water habitats are also invariably provided with relatively smaller gills in the brackish habitats than is characteristic of them in fresh water. The phenomenon of gill reduction relates similarly to all four instars, and individual variation in gill size for a species at a time and place is usually quite limited. There is also a considerable degree of correlation of gill reduction with salinity increase across a typical salt marsh within a single species. Thus the gill ratios—length of gill/length of dorsal saddle—of 4th instar *punctodes* from *Myrica* Type stations with a mean salinity of 30.9 average 1/1, while the comparable figure for *Triglochin* Type stations with a mean salinity of 631.4 is only about 6/10. The average ratio for the huge *punctodes* population on Mendenhall Flats, 5/10, probably represents the most characteristic size for the species in coastal waters. Thus the average reduction of gills is not nearly as great as for *Aëdes sollicitans* and *detritus* of North Atlantic salt marshes, which are both more restricted to salt habitats and presumably geologically older salt-marsh breeders. Finally, striking contrasts in gill development were noted in comparing bog larvae with the same species from salt marsh, e.g.: *communis* from bogs—25/10, from salt-marsh—3/10–15/10; *impiger* from bogs—28/10, from salt-marsh—5/10–14/10; *flavescens* from fresh water (Stage *et al.*, 1952)—20/10, from salt-marsh—2/10.

Notes on Species. *Aëdes punctodes* Dyar. These larvae were as abundant as *punctor* on the Upper Cook Inlet marshes in the four principal habitat types *in toto*. *Punctodes,* however, is the only species which thrives in the most saline waters (1,000 ppht.). Myriads of the newly hatched larvae appeared about the last of April. A few old larvae were still present in August. The anal gills are blunt, relatively short; the ratio is quite variable, 2/5–1/1.

Aëdes punctor (Kby.). These larvae characterize the fresher habitats and are, so far as is known, about equal numerically to *punctodes* on the marsh as a whole, being relatively less common in saltier types of marshes, e.g. Mendenhall Flats, Southeastern Alaska. The earliest larvae appear about a week later than *punctodes* because of the earlier melting of pools in the open, salt *Triglochin* zone. Some larvae linger until August, acquiring coats of vorticellids, especially heavy on the gills. *Punctor* gills are more pointed, attenuate, and longer than *punctodes* in the same collection; the ratio is usually over 12/10, ranging from 5/10 to 15/10 in salt marshes.

Aëdes hexodontus Dyar. This is a doubtful record from a single *Myrica* pothole.

Aëdes impiger (Wlk.). The species was taken in all five habitat types but was common chiefly in *Myrica* potholes associated with *communis* and, of course, *punctor* and *punctodes*. Some eggs hatch even earlier than *punctor* (as first noted by Dr. Sailer of the Alaska Insect Project), and there are small larvae present from mid-April to July. The gills are variable, budlike to long; the ratio is from 3/10 to 13/10, averaging about 6/10.

Aëdes communis (DeG.). Larvae were taken in all four major habitat types, but they occur especially in *Myrica* potholes. They were almost invariably associated with *impiger, punctor* and *punctodes*. Like *impiger, communis* eggs may hatch as early as mid-April in small melt holes in the ice. The anal gills are quite variable, short to long, usually attenuate; the ratio is 3/10 to 15/10, averaging about 13/10. In collections in which both occur, *communis* has much longer gills than *impiger*.

Aëdes excrucians (Wlk.). The larvae are characteristic of the deeper water of Fresh and Brackish *Carex* Type marshes but also occurred in one *Triglochin* Type station with an average salinity of 830. The smallest (2d instar) larvae collected were taken from the middle of May to the end of June. The apex of the dorsal saddle is peculiar in these brackish *excrucians*

in possessing spinelike denticles. The gills vary greatly, from budlike to attenuate; the ratios range from 2/10 to 14/10, averaging about 1/1.

Aëdes pionips Dyar. This common species of fresh water is evidently of no importance in salt marshes, being scarce in a single collection of the Fresh *Carex* Type and in one *Myrica* pothole in late May and early June. The gills are rather attenuate; the ratios are 11/10 (*Myrica*) and 9/10 (Fresh *Carex*).

Aëdes flavescens (Müller). Although the adults occurred in large numbers on two of the study marshes, only a few *flavescens* larvae were dipped, always in Brackish *Carex* Type stations early in June. The gills are minute, budlike, almost globular; the average ratio was 2/10.

Aëdes cinereus (Meigen). The unmistakable larvae of this species of the 2d instar were present in a single collection of the Brackish *Carex* Type. The gills are attenuated; the ratio was 11/10.

Culiseta impatiens (Wlk.). Fourth stage larvae were taken a total of only three times in Fresh and Brackish *Carex* Type stations, but the rafts and small larvae were not infrequently collected, though never in the *Triglochin* Type habitat. Perhaps this exceedingly common Alaskan fresh-water mosquito is at an early stage of developing resistance to salt.

Culiseta alaskaënsis (Ludl.). Like *impatiens,* this species is presumably only adventitious in saline waters. It was collected (1st-3d instars) in one Brackish and one Fresh *Carex* Type station associated with its congeners, *impatiens* and *morsitans.*

Culiseta morsitans (Theob.). The 4th instar of this species was not found in other saline waters than the exceptional *Carex* stations where a few *C. impatiens* and *alaskaënsis* were its associates. The striking circumstance that all three *Culiseta* developed to the 3d or 4th instar, so far as is known, only in the same two identical stations may be meaningful.

Salinity tests. The degree of salt tolerance of larval *Culiseta impatiens* and *alaskaënsis* was determined approximately in the laboratory. Sibs from individual rafts of these easily reared mosquitoes were simply placed in graded salinities and survival after 96 hours was noted. In general the *impatiens* larvae failed to molt with the controls and all died in the four days in water more saline than 200. For *alaskaënsis* the same was true for salinities exceeding only 50. The field-collected *Aëdes* larvae, however, were less satisfactory to work with, surviving well regardless of salinity, only sometimes in large pans. As a result the data were variable and inconsistent. The adaptation of mosquito larvae to increasing salinity discovered by Wigglesworth (1933) was not the important disturbing factor, however. For example, "unadapted" 4th instar *communis* larvae and pupae from interior Alaska were compared with similar coastal larvae and pupae. Both lots were collected in *Myrica* potholes, the former of fresh water, the latter having about 55 ppht. chlorine. Of the interior *communis,* 90% pupated and emerged in test salinities of 20 to 500. In fact the most saline vessel increased from about 500 to about 700 and yet 80% pupated and emerged from it. For coastal *communis* larvae, which seem to have been less robust, about 10% less pupated and emerged from the same salinities. The pupae from the two sources were similarly quite salt-resistant. From the interior, 90% emerged (80% in the most saline: 500), while for the coastal pupae 65% emerged. Thus regardless of previous experience large larvae and pupae of this species tolerated about 500. The salt tolerance of *punctodes* might be greater since that species occurs naturally in higher salinities. The *punctodes* tests were ten series of 240 larvae each, and different instars were studied as they became available on the Mendenhall Flats where *punctodes* occurred in nearly pure culture. Both tides and heavy rains there led to wide fluctuations of the salinities from which the experimental larvae were taken. Unfortunately the variable results are difficult to condense or generalize upon. An attempted summary follows:

(1) 1st instar taken in 12 ppht., tested in high salinities only, gave:
  (a) for 640 (after 96 hours)—40% (survival)
  (b) for 835—10%
  (c) 900–1,000—1%. These larvae were not fed.

(2) 1st instar (same source), fed ground whole wheat bread, gave:
  (a) 695—60%
  (b) 855—50%
  (c) 900–1,000—8½%. However, except for (a), these larvae did not molt with the low-salinity controls.

(3) 1st instar larvae from a salt habitat, 530, fed as above:
  (a) 135–500—90%
  (b) 605—40%
  (c) 625—70%
  (d) 760—60%
  These larvae seemed to show adaptation, but of 30 at 605–760 only 3 survived for 10 days.

(4) Tests with 2d instar larvae were unsuccessful; the larvae died in controls and test salinities alike.

(5) 3d instar taken in 180:
  (a) 395–560—25%
  (b) 70–260—56%

(6) 4th instar taken in 6 (after rains):
  (a) 460—20%
  (b) 295–335—17½%
  Pupation and emergence were normal for only one class, the (b).

(7) No other data on pupae than 6 (b) immediately above.

While these few and variable results scarcely permit general conclusions on the salt tolerance of *punctodes*, it is probably significant that there were almost invariably individual larvae, even of the delicate 2d instar, which survived 10–30 days in test salinities up to 1,000. This species is difficult to rear in small vessels. It is not improbable that the positive results (survival of a few) are more significant in relation to salt tolerance than the high mortalities. Viewed in this way the experiments do not appear completely at variance with field data showing great numbers of *punctodes* larvae at 700–800. However, there was neither molting nor growth manifested by many of these long-term survivors, and they were usually noticeably less active than is normal. If *communis* be regarded as just as salt tolerant as *punctodes* on the basis of these preliminary findings, then the females have not acquired the habit of ovipositing as far out on the marsh as *punctodes*.

NATURAL CONTROL. Natural control of mosquitoes by predaceous insects is negligible on these Alaskan salt marshes. *Carex* marshes, however, support consequential numbers of dytiscid beetles and their larvae after about mid-June, and the doughty predatory midge larvae of *Eucorethra underwoodi* Underwood and *Mochlonyx* sp. clear certain potholes of wigglers. In the main, however, insect predators are too few or too late to effect a noticeable reduction of *Aëdes* larvae.

On the other hand, predation by fishes, which is of no practical significance in Alaskan fresh-water mosquito breeding, is of the greatest importance in some saline mosquito habitats. The northern stickleback, *Gasterosteus aculeatus* L., and to a very much lesser extent, *Pungitius pungitius* (L.), spawn in the *Triglochin* and Brackish *Carex* Type habitats, access being provided especially by tidal bores in the Upper Cook Inlet. These bores, occurring in connection with the 30–35 foot spring tides resemble small tidal waves 1–12 feet high. The salinity* of the new water is not excessive and there is no evidence of mosquito mortality in flooded pools. The fish and their fry, nevertheless, eliminate all wigglers from the depressions in which they spawn. This phenomenon is an annual one and it was observed not only in the Upper Cook Inlet in 1950 and 1951 but also on the Mendenhall Flats in 1952. In the latter location, the sticklebacks, all *G. aculeatus*, came in when peak numbers of larvae were in the 4th instar

*Cook Inlet water average salinities, 1950: May 12—940; May 23—1172; May 29—1220; June 5—1042; June 16—342; June 24—677. The summer freshening represents glacial melt.

and the voracity of the fish was dramatically demonstrated by the disappearance of mosquitoes in stickleback pools. The outer half, approximately, of the marsh was affected. In larviciding, care should be taken to insure proper timing by tide tables and perhaps by low dosages to spare these useful little fish.

PARASITES AND ATTACHED ORGANISMS. Coatings of vorticellids crowded especially on the gills have been mentioned for *Aëdes punctor* larvae in *Myrica* potholes. These stalked peritrichs evidently belong to a single nonparasitic species characteristic of mosquito larvae in shaded, nearly fresh, saline habitats. A few instances were noted for larvae from the most dense *Carex* Type stations. Since Kudo warns that specific determination is very difficult in this group it must suffice to note a similarity to *Vorticella alba* Fromentel. The following *Aëdes* larvae were hosts: *punctor, punctodes, communis, impiger,* and *pionips.* Another attached organism occurring on *Aëdes punctor* and *flavescens* in a single collection is an asterisk-shaped water mold, apparently not parasitic. In fresh-water habitats somewhat above the high tidal limits (Southeastern Alaska) mermithid parasites, probably identical to the worms described by Stabler (1952) for other mosquito hosts, were locally common chiefly in the thoraces of large *Aëdes* larvae: *impiger, cinereus, punctor, communis.* They were not found in any species in saline waters, however.

DISCUSSION. The data of this paper were selected as representative, so far as is known, of salt marsh mosquito breeding in the subarctic and temperate regions of Alaska. To what extent the generalizations apply to Aleutian or arctic marshes is uncertain. A reduction in number of mosquito species northward into the arctic or westward out the Aleutian chain comparable to that which occurs in the fresh-water habitats may be conjectured. Of more immediate value than further distribution data are answers to basic life-history questions, e.g. to what extent are the adult habits of these salt-marsh mosquitoes unlike those of the fresh-water species with which they are identified, or, in a larger sense, are not the salt forms distinct races? In consideration for its preponderant importance on the marshes, the biology of adult *punctodes* deserves early study. If, unlike fresh-water *punctor,* the adult is not a forest mosquito, *punctodes* may disperse quite differently. This would also possibly enable it to exist on the treeless Aleutians and far into the arctic.

SUMMARY. Mosquitoes breeding in salt marshes were studied in two widely separated regions of Alaska, one subarctic, the other temperate. With reference to the former region, five types of larval habitats based chiefly on salinity and zones of plants are proposed: (1) *Triglochin;* (2) Brackish *Carex;* (3) Fresh *Carex;* (4) *Myrica;* (5) Seepage.

Twelve species of northern fresh-water mosquito larvae were collected in these brackish habitats, of which six species of *Aëdes* are of chief importance, viz.: *punctodes* Dyar, *punctor* (Kby.), *impiger* (Wlk.), *communis* (DeG.), *excrucians* (Wlk.), and *flavescens* (Müller).

Aëdes punctodes, which is shown to be the principal Alaskan salt-marsh mosquito, predominates especially in the more saline waters, while the closely related *punctor* prefers the least brackish.

An attempt, only partly successful, to determine approximately the salt tolerance of *punctodes* and *communis* larvae in the laboratory suggests resistance to salinities equivalent to 500 parts per hundred thousand of chlorine, at least.

Predation by the stickleback, *Gasterosteus aculeatus* L., is shown to be significant in the natural control of *punctodes.*

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THE PESTICIDES INDUSTRY

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I certainly appreciate this opportunity to appear before the American Mosquito Control Association to present some of the pesticide industry's views on behalf of the National Agricultural Chemicals Association.

As the control of insects increases in complexity the difficulty in deriving the most from research activities proportionately increases. Whether the pests affect the health of man directly or destroy his food and fiber crops, modern pest control has become a vast field of endeavor on the part of agriculturalists and public health officials whose work is so integrated that much is lost if either group of workers ignores the progress in the related fields.

The control of mosquitoes and the tremendous reduction in diseases carried by these insects is a modern phenomenon. Without the coordinated program on a national and international scale I feel certain that only a meager portion of such endeavors could have been attained. The coordination brought about through such meetings as this has incalculable value in the progress of any program of pest control.

The two fields of agricultural pest control and public health programs have expanded concurrently and out of the same industrial hopper come the products used in protecting man's health and his supply of food and fiber. The introduction of the organic chemicals brought about a complete revolution in the control of pests. I need not point out to you what this has meant toward raising the standard of living for the peoples of many of the free countries of the world. Yet, you all realize that we have only started to recognize the potentialities of controlling man's biggest competitors. At the recent meeting of the National Agricultural Chemicals Association Dr. Charles E. Palm, President of the Entomological Society of America, pointed out that world unrest could possibly be alleviated through the use of pesticides to improve man's health and his food supply. He explained that poor health and empty stomachs are not conducive to a satisfied man. Such an outlook is worthy of endorsement.

You can reasonably ask, are these chemicals available in sufficient supply to cover any necessities to improve health standards and overcome agricultural pest problems of the world. The United States pesticides industry alone has facilities for the manufacture of sufficient chemicals for public health programs throughout the free world and can furnish these materials if sufficient advance notice is given to allow for their production.

During the past two years, at the instigation of several federal agencies, our industry made a tremendous expansion of its facilities for the production of organic chemicals. In addition, many of our companies have established foreign plants for the production of basic chemicals and for formulating these into finished products.

Many other countries have been supplying and will continue to supply much of

the needed materials for public health and agricultural programs. The coordination of international health and agricultural programs has aided materially in establishing the demand for these materials in various parts of the world. The international meetings of societies and sponsorship of international conclaves by the United Nations have aided in coordinating much of the information that is needed by the pesticides industry to distribute its products properly.

At the present time the National Agricultural Chemicals Association through its Committee on Exports is conducting a study of those government agencies which have information on the export of pesticides.

We are attempting to clarify the interrelationship of these particular agencies and their responsibility for the export of pesticides. Along with this compilation of United States government agencies concerned with pesticides, the Committee is including those international sources of information regarding chemicals used in the promotion of public health programs and in world agricultural production. When this study has been completed, the information will be made available to such organizations as yours here, and to other interested groups.

Under the United Nations auspices money has been made available from the United Nations International Children's Emergency Fund to build plants for the production of DDT in Egypt, Pakistan, Ceylon, and India. The World Health Organization will supply the technical assistance necessary to begin their operations. Once these manufacturing facilities are in production the ownership of them is to pass to the state. The merits of this type of state-operated and controlled manufacturing facilities are yet to be determined.

There have been many problems faced by the industry which have been attendant on the introduction of organic pesticides and the subsequent expanding of the field of pest control. One of the problems in which you are interested is restrictive legislation affecting the marketing and use of pesticides. During this year over 150 state bills have been introduced into the state legislatures affecting the distribution and use of products at the state level. These bills involve permits for use; restrictive labor requirements; excessive fees for marketing products within a state; excessive research requirements; and residue tolerances.

On the federal level the same situation now exists. Early this year Representative James J. Delaney of New York introduced a bill to amend the Food, Drug, and Cosmetic Act along the lines of the Delaney Committee majority report of last year. This is Bill number H.R. 2245.

On March 26, Representative A. L. Miller of Nebraska introduced a second bill called "The Pesticides Residue Amendment to the Federal Food, Drug, and Cosmetic Act", H.R. 4277. Senator George D. Aiken of Vermont introduced Senate Bill number 1542 which is exactly the same as the bill introduced by Representative Miller.

This new federal legislation is the outgrowth of the Delaney Committee hearings on the use of chemicals in the production of food and in the preparation of foods and cosmetics. The new legislation does not in any way affect the Federal Insecticide Act. The legislation grew out of a fear, by some, that the general public was not fully protected against pesticidal residues in foods. But it affects the marketing and use of all pesticides—including those used in public health programs—so you will probably be interested in this proposed legislation.

We believe that the new legislation introduced by Representative Miller and Senator Aiken, should be vigorously endorsed by all manufacturers of pesticides, organizations concerned with agricultural production, with public health programs and by research agencies and the land grant colleges. Contrarily, all of these groups should oppose the Delaney Bill, H.R. 2245, which was introduced in the House earlier this year.

This new legislation, we feel confident,

adequately protects the public health and at the same time protects the manufacturer of the pesticides, the growers, and handlers of commodities on which pesticides are used.

1. It recognizes that the problems involved in the use of pesticides on food are vastly different from those involved in the use of intentional chemical additives. Accordingly, the proposal sets up a separate section in the Federal Food, Drug, and Cosmetic Act relating specifically to pesticides.

2. It recognizes that the most appropriate manner of improving present pesticide controls is by improving the tolerance-setting procedure rather than along lines suggested in previous administration proposals. The proposal requires the prompt setting of tolerances for pesticides designed for food use upon the petition of the interested person or upon the initiation of the Federal Security Administrator. Specific time limits for administrative action are prescribed. Costly and cumbersome public hearings are avoided. The unrealistic requirement of establishing necessity for use by formal proof is replaced by a procedure whereby the usefulness of a pesticide is certified by the Secretary of Agriculture to the Federal Security Administrator.

3. Provision is made for advisory committees composed of qualified experts to advise and consult with the Federal Security Administrator in connection with tolerances. This avoids placing complete responsibility over highly technical questions of science in the province of one agency. The Federal Security Agency, Industry, and the National Research Council would all have a voice in the selection of any advisory committee set up to pass upon a proposed tolerance.

4. It provides for a method of court review whereby the findings of the Administrator in connection with a tolerance would be independently evaluated by the court instead of being the subject of the rubber stamp as is involved in numerous appeal procedures.

5. Provision is made for the integration of tolerances which may be issued as a result of the 1950 hearings, for exempting pesticides for which a tolerance is not necessary from the tolerance procedure, for protecting and encouraging research, and for coordinating existing controls over pesticides under the Federal Insecticide, Fungicide and Rodenticide Act.

Both the federal and state laws which control the marketing and use of pesticides must be practicable in nature. If not, they restrict the introduction of new products and discourage basic research in the discovery of new chemicals which we so badly need to overcome much of the resistance to chemicals that insects are developing. You have already heard considerable comment concerning new products, one of the most recent of which is granular insecticides.

It has been quite definitely proven that under certain conditions, adverse for conventional dust and spray applications, granular insecticides have overcome several difficulties. But there are many questions to be answered concerning these products, offering a fertile field for research. A few of the points that need investigation are:

1. Optimum size range of granular base material;

2. Rate of release of toxicant;

3. Rate of disintegration of the granular material and its effect on the control of mosquito larvae and soil inhabiting insects;

4. Methods of formulation and their relation to control;

5. Studies on application equipment for granular insecticides.

There is insufficient time for me to go into the problem of adapting application equipment to the use of modern pest control chemicals and their complex formulations. I would like to mention, however, that there is a committee at work coordinating the application research activities of the chemical and machinery industries and the research groups of the land grant colleges and the U. S. Department of Agriculture. Our Association will be glad to furnish you information on this committee upon request.

There is one warning which I should

like to leave with you in regard to the use of pesticides, whether it be for the purpose of improving the general welfare of man through agricultural pest control, or through the control of insects transmitting diseases. We have been bombarded in the past with many adverse press stories regarding the hazard to public health caused by the application of these materials.

Everyone who is connected with the use of pesticides has a responsibility for the proper application of these materials. The records have proved that much of the criticism and a great deal of the hazard comes from improper use of these products. A great deal of the misuse of pesticides can be overcome by reading the labels on the materials and following directions specifically. The continued adequate supply and wide choice of these materials depends in great part upon responsibility in their proper use.

As a representative of the National Agricultural Chemicals Association, I wish to extend to you an invitation to consult our Association about any situation or problem which you may have concerning the use of pesticides. Our industry is doing everything possible to promote the proper use of its products and offers its services to expand the use of pest control in agricultural and public health fields.

MOTIVES BEHIND MOSQUITO FLIGHTS

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I'm sure if I were in the audience instead of here, I'd be asking why in the world does this man want to talk about motives, of all things, in mosquito flights. Let me tell you why, at the outset. We are working with migratory mosquitoes in Florida. We are learning many things about our salt marsh mosquitoes. But when asked about our findings, we frequently make ourselves difficult to understand—not because we talk in terms too technical or anything of the sort, but mainly because many features of migratory behavior which we take for granted, being continually concerned with them, appear differently to others. What I mean is that the very great differences between migratory flights and other mosquito flights which we are so accustomed to observing seem not to be equally appreciated by others. The best examples of this are questions asked about "flight range" of salt marsh mosquitoes—a matter which strikes us as meaning little when it is expected to mean something quite concrete. It's only because migratory flights differ from other flights chiefly in motivation that I'm led to talk of motives. We just want and need to understand one another more clearly.

When we speak of motives, we must put ourselves in the subject's boots. It's not easy to put yourself in a mosquito's position, but with a little imagination and perhaps a lot of daring, it can be done. Our guess is that a mosquito is always in one or the other of two opposite states: either it is at ease or it is uneasy. In us, being at ease or not depends on more than strictly biological conditions; but in mosquitoes purely biological factors can explain either their actions or their feelings. It is difficult for us to refrain from projecting our consciousness and our thinking into the behavior of an insect. Most of what we do, at least in our sober moments, has a purpose. No one would seriously claim an insect thinks, and no one could *prove* it is even conscious. Yet many do not hesitate to say that mosquitoes act with a purpose—that is, with a beforehand knowledge of what they are about to do. This is pure delusion; the insect is a living automaton.

By motives in mosquitoes, therefore, we

understand not an emotion as found in us, and, still less, an act of will. We mean simply a state of nervous tone, an altogether mechanical state of affairs in the nervous machinery. When all the parts it serves are satisfied, that machinery may be said to be in equilibrium and the mosquito is at ease and resting. If then any unsatisfaction develops, any physiological need or want in any part, the machinery is out of equilibrium and the mosquito is uneasy. This state of uneasiness gears the machinery in such a way that the mosquito becomes active and searches for whatever stimuli will guide it to the satisfaction of the need. This active seeking of stimuli is called appetence. Examples of appetential behavior would be a hungry female searching for a blood meal, a gravid female looking for a place to deposit its eggs, or a mosquito of either sex looking for a resting place. This concept of appetence is nothing new, and it is accepted by most students of animal behavior. Something very much of the same sort lies at the base of human behavior, although in us there are psychological complications so great that appetential behavior is relegated to the subconscious.

Now, let us consider two case histories of flight in the salt marsh mosquito, *Aedes taeniorhynchus*. It was just past sunset, down at the edge of a large puddle in a salt marsh. Female 1 was leaving her birthplace and female 2 was biting the observer. Number 1 had struggled out of her pupal case at noon. Her first weak flight was a matter of a few inches from the water's edge to the base of a grass clump. She idled away the hot afternoon hours there in the moist shade. As the sun set, she stirred a little. She started climbing. The darker it got the higher she climbed until she was perched at the very tip of the grass culm. Suddenly she let go, flew straight up a few feet, then levelled off in a bee-line to the northward. Within twenty feet of the grass she was invisible in the dusk, but within a short time she would be miles away. At about the time she left, female 2 bit the observer on the forehead. It was her first taste of blood. Ten miles away and three days ago, she had emerged from a marsh much like this one. Somewhere along the line she had mated. When female 1 was emerging at noon, this female 2 was resting on the ground in the shade of dead sea-grape leaves some 200 yards away. There she stayed idle until the sun turned red, preparing to set. She became restless and flew away. Her flight was more leisurely than number 1's and not straightaway but zig-zag and up and down. When she came close enough to the observer watching number 1, she set her course and made straight for his forehead, where he first became aware of her.

By definition, number 1's flight was non-appetential, and number 2's appetential. When number 2 left the sea-grape leaves at sunset, she was hungry. She didn't smell blood the minute she left; she left, searching for that smell. She was in a state of appetence and flew about looking for a clue. Her flight was not oriented by the smell of blood or breath but by something inside that said: "keep flying until you cross the scent of a warm-blooded mammal." When she came close enough to the observer, her antennae tingled to the odor that then oriented her straight in his direction. Things were a lot different with number 1. When she left the top of that grass spear, she was not hungry. She had brought with her from the pupal stage enough food reserve to yield energy for quite awhile yet. She didn't need anything badly enough to unease her. But when the illumination had dropped to a certain point, she couldn't resist the urge to fly. Once on the wing, this urge was satisfied as long as she flew. There was nothing inside telling her to search for this or that stimulus; there was no appetence, she was comfortable and content just flying. Without anything inside nagging her on and thereby orienting her flight, she simply took the path of least resistance, environmentally speaking, and so made a bee-line in whatever direction and at whatever speed the environment dictated. *She was migrating.*

I hope you'll overlook the simplifica-

tions used in painting this picture. Actually, every least phase of animal activity is fantastically complex when examined for causes. It may seem presumptuous even to talk of causes without knowing more of what in fact happens. Nevertheless, we must suppose a little now, just for the sake of better understanding one another. Investigations of mosquito flight are multiplying fast, and I'm afraid we are rapidly reaching rampant confusion unless we take stock of what we already know and agree on some fundamental facts. Some of us are working with non-migratory and others with migratory mosquitoes. This is a difference so great that our findings appear contradictory. We would do well to seek agreement on what constitutes migration in mosquitoes and what it implies. After a considerable study of what others have written about insect migration, I am led to believe that it differs from other flights only by its lack of appetential motivation. Let us see, now, what ensues from such a basic premise.

In insects, migration is movement away from the terrain of normal satisfaction of biological needs. It is associated with outbreak production and it is characterized by the unidirectional flight of individuals. In butterflies and locusts, an enormous amount of investigation has shown that migrations are not directed at any special goal but are merely the result of a locomotory drive channeled by environmental circumstances. What little we know of mosquito migration gives no support whatever to any other explanation but the same one. Whether the locomotory drive replaces or suppresses the usual appetential flights does not matter; what matters is that it exists as an all-consuming impellation which maintains the insect in flight without special motivation and therefore at the mercy of environmental orientation.

Every intensive study of insect migration has come up with essentially the same patterns of events. First of all, the necessary locomotory drive is released only at certain times in the individual insect's life. Secondly, the weather sets a limit to the exercise of the locomotory drive. These two factors together, one physiological and the other ecological, set a time limit to an individual insect's migratory flight. This time limit then establishes the distance limit in combination with whatever ground speed is allowed by the insect's flight powers and the wind. And finally the direction of the migratory flight is determined by the accident of weather and terrain as affecting the insect's peculiar reactions. If all this is so, you might say, a supposedly migratory insect may either migrate or not migrate, may go north, south, east or west, may fly 5 miles an hour or 20, and may migrate 10 feet, 10 yards, or 10 miles! This is exactly the case; migration is but the expression of an average.

There is no need to consider migration as a very special kind of behavior. Neither is it logical to presuppose a special migratory instinct or that basic mechanisms for migration exist in certain species and not in others, for in either case the physiological and morphological specializations assumed would be too fundamental and unique to criss-cross the genealogical lines the way they must. Even if facilitated in some cases by certain adaptations, migratory behavior must be a phase of normal behavior latent in entire families or orders but varying among species only in the extent of its exercise. We do not yet know to what extent even *Aedes aegypti* may migrate. The longer the locomotory drive persists and the more its interval is atune with weather characteristics that will allow its exercise the more migratory is the species. Given a species that has these properties to the extent that salt marsh mosquitoes have them, we may certainly speak of that insect as a migratory mosquito. But we must not let this label misguide us. To what extent a particular brood of that migratory mosquito species will migrate, if at all, is something else again. This will depend on the topography, which in its particulars will vary about every breeding area, and on the weather, which also will vary in its particulars with every emergence.

There's no telling in advance where or how far an individual salt marsh mosquito

will migrate from its site of emergence. We can talk only of averages. For instance, with *Aedes taeniorhynchus* we may be able some day to say: (1) in the female the locomotory drive is released for 48 hours, (2) the average weather will allow the female to exercise its locomotory drive during 6 of those 48 hours. We would then have the average migratory period for the species: 6 hours. We may then learn that the average ground speed of migration is two miles per hour. Thus we would conclude that the average length of migration is 12 miles. Narrowing this down to a certain area, we may be able to say that from *this* breeding area, average weather conditions will channel the average flight northward for 12 miles.

All this talk of averages may be very unsatisfying to the man looking for something concrete to guide his mosquito control planning. But it won't help to contradict nature. If averages it is, then the thing to do is find ways of using averages. It will do little good to hold on to rigid rules and definitions that have no meaning in reality. One such unrealistic rule is that every mosquito species must have what is called a "flight range." It's true that in species where the dispersal is almost altogether appetential, there may be a fairly constant limit to dispersal from breeding areas which can be called a flight range for the species. With such species the flight range may vary directly with the intensity of breeding; and the adult density may decrease regularly with distance from breeding area. These concepts are all based on dispersal by appetential flight, so characteristic of the much-studied anophelines. But such generalizations cannot be applied to migratory species where one long non-appetential flight has more to do with the final dispersion than the thousands of short, appetential flights made later. With highly migratory mosquito species the concept of flight range, with every one of its connotations, has little meaning and less application. Dispersion in mosquitoes, therefore, is by random scattering in search of blood, oviposition sites, resting places or whatever else the insect requires. This applies to all mosquitoes. But the thing to remember is that in some species this appetential dispersal was preceded by a migratory flight which may have transplanted the entire population many miles before it even began the normal or appetential dispersal. From the standpoint of total dispersion from the breeding area, it therefore makes a huge difference whether or not migratory flights are involved.

I hope I can close on another note than did the mosquito biologists who reported: "The large amount of experimental work which we performed has on the whole added to the pre-existing confusion." There is no denying the existing confusion on mosquito dispersal. Whenever a topic is confused and fellow-workers fail to understand one another, it is usually because something fundamental is being overlooked. In the case of mosquito flights, I feel certain the fundamental fact overlooked is their motivation.

HYBRIDIZATION EXPERIMENTS WITH *CULEX PIPIENS* AND *C. QUINQUEFASCIATUS* (DIPTERA, CULICIDAE)[1]

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It has been shown that *Culex pipiens* and *C. quinquefasciatus* will freely interbreed in the laboratory, that fertile hybrids are obtained from either cross, and that hybrid populations can be maintained with undiminished vigor for a number of generations (reviewed by Barr and Kartman, 1951, and Mattingly, *et al.*, 1951). Furthermore, the presence in nature of specimens similar to laboratory hybrids has been demonstrated (Sundararaman, 1949). Evaluating these phenomena by means of Mayr's (1942, 120) species concept, Farid (1949) and Sundararaman (1949) have both recommended that *pipiens* and *quinquefasciatus* be treated as sub-species.

One question that immediately comes to mind when the above facts are considered concerns the fate of hybrids when exposed to populations of the parents. Sundararaman (1949) speculated that hybrid stocks of *pipiens-quinquefasciatus* may revert to parent types through backcrossing.

The study reported in this paper was made to investigate this possibility. While the work was in progress, a paper describing a similar investigation by Barr and Kartman (1951) was published. However, since the present study utilized completely different parent stocks it was thought worthwhile to complete the work.

The *pipiens* adults used were reared from a sample of the Cairo population collected as mature larvae and pupae from a cement basin in a mosque (coll. 257, June and July 1951, elevation approximately sea level). The biological and morphological characteristics of the Egyptian Cairo population have been described in detail by Knight and Abdel Malek (1951), who suggested as a result of their study that it should be treated as an urban biotype of *pipiens* and be given the non-committal name of form "molestus."

The *quinquefasciatus* adults were part of a colony established from a larval collection made at Asmara, Eritrea in a small cement basin (coll. 236, 29 June 1951, elevation approximately 7,500 feet). Nothing definite is known of the biological characteristics of this population except that it will feed on infant laboratory mice and rats but not on man, pigeon, and toad; and that it will copulate in a space as small as 177 cubic inches.

Two morphological characters, one adult and one larval, were used to evaluate the effects of hybridization. The adult character used was the DV/D ratio of the male genitalia. In this ratio, which was developed by Sundararaman (1949), DV is the distance between the outer apical margins of the dorsal and ventral arms (measured for each side and averaged), and D is the distance between the outer apical margins of the dorsal arms. Standard procedures were used to prepare male genitalia for determination of the DV/D ratio. However, in contrast to the method employed by Sundararaman (1949), each cover slip was supported by the use of strips of thin plastic. No difficulty is experienced in determining the DV/D ratio for pure stocks of *pipiens* or *quinquefasciatus*. However, the measuring of the hybrid specimens is rather difficult because of the profound changes which take place in the shape of the distal portion of the dorsal arms.

The larval character used was the num-

[1] The opinions or conclusions contained herein are those of the author and are not to be construed as official or reflecting the views of the Navy Department or of the Naval Service at large.

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ber of branches possessed by the subdorsal hair on abdominal segment III (hair 4 of Belkin, 1950). This character was suggested as a means of separating the larvae of *pipiens* and *quinquefasciatus* by Howard, Dyar, and Knab (1915, 228). The determination of the branching of this hair was made from the larval skins. However, it can be accomplished from the living larva without too much difficulty. This hair is paired and in each case both members of the pair were examined. The subdorsal hair of segment IV may also be used but is slightly less trustworthy than on segment III because it exhibits more variability.

Larvae were fed from hatching until the fourth day with a dilute aqueous suspension of Mead's brewer's yeast powder (0.1 gram per egg raft). On the fourth day, larvae were counted and placed in 500 cc. of water in large crystallizing dishes. Lyphilized horse serum was dissolved in 500 cc. of water at the rate of 0.008 gram per larva. Brewer's yeast powder was again added, this time at the rate of 0.002 gram per larva. The resulting mixture was then added to the dish. If more than 100 larvae were present in a dish, it was found advisable to add a third volume of 500 cc. of water. Each dish was then covered with a glass plate and not touched further until pupation began. This procedure was worked out to avoid the great amount of contamination which so often resulted when the standard foods such as ground dog biscuit, rabbit-food pellets, or dried bread were used. Also, it retarded the otherwise rapid formation of a surface film.

Pupae were isolated in cotton-stoppered two ounce bottles. Upon emergence the adults were released in the desired combinations in laboratory mouse jars (possessing a volume of 375 cubic inches) which were closed with stockinette sleeves held in place by rubber bands. Oviposition dishes and cotton wicks soaked in table sugar solution were available at all times. Beginning on approximately the fourth day following the release of adults in the jars, infant white mice or rats were taped onto small cards and placed in the jars overnight. No records were kept as to the percentage of females taking blood from these sources, but it was estimated to be about 25–30 percent. Egg rafts were collected daily and isolated onto water in china soup bowls.

Not all of the females of this population of *quinquefasciatus* successfully copulated in the laboratory. In one case, 10 females were dissected 48 hours after 12 males and 12 females were confined in a glass cylinder with a volume of 177 cubic inches, and examination of the spermathecae disclosed that only six of the 10 females were fertilized. On another occasion, females from a small colony in a mouse jar (volume of 375 cubic inches) were dissected on the eleventh day following the mixing of the sexes and only five of them were fertilized. On the other hand, approximately 100 percent fertilization occurred within 96 hours in the *pipiens* population (in volume of 177 cubic inches).

The parent generation of *pipiens* and the F_1 generation of *quinquefasciatus* were used for the straight crosses and for the first backcrosses. The second backcrosses were made to the parent generation of *pipiens* (accomplished by collecting more larvae from the same breeding site) and to the F_2 generation of *quinquefasciatus*. The use of the F_1 generation of *quinquefasciatus* for the straight crosses was necessitated by the small number of individuals in the parent generation.

The straight crosses were made in both directions. The first backcrosses were made in all eight possible combinations. The second backcrosses were made in only the following four combinations: P ♂ × PPq ♀, PPq ♂ × q ♀, QPq ♂ × q ♀, and Q ♂ × QPq ♀ (males are capitalized and placed before females). Neither the straight crosses nor the backcrosses were carried beyond the first generation.

Care was taken in the selection of samples for examination to represent as many egg rafts from each separate population as possible. The actual number of egg rafts from each population ranged from five to 17.

RESULTS. As stated previously, the effects of crossing and backcrossing were determined for two morphological characters, one adult (DV/D ratio) and one larval (number of branches of hair 4 of abdominal segment III). These two characters are the only reliable morphological diagnostic characters presently known for the separation of *pipiens* and *quinquefasciatus,* and the latter character is only diagnostic when used on a percentage basis.

DV/D RATIO. The DV/D ratios for the parent, straight-crossed, and backcrossed stocks are graphically presented in Figure 1. In each case, the solid line indicates the observed range of variation, the cross line the mean, and the dash line the mean plus and minus three standard deviations. The data below these lines present the number of examples measured from each population (N), the means and their standard errors (M), and the standard deviations and their standard errors (S.D.).

It can be seen that both the observed and theoretical ranges of the DV/D ratio were distinct in the two parent stocks. The hybrids obtained by crossing the parent stocks in both directions were intermediate. Similarly, the populations resulting from the backcrossing of the hybrid strains were in each case intermediate between the hybrid and the parent. This shift towards the parent is more pronounced with *pipiens* than it is with *quinquefasciatus.*

Of interest is the fact that, in each case, the observed range of variation is positively skewed. Also of interest, is the fact that this range is considerably greater in *quinquefasciatus* and in the backcrosses to *quinquefasciatus* than in the case of *pipiens.* No explanation for these two peculiarities can be advanced at present.

HAIR 4 OF AB-III. The percentage occurrence of singleness (unbranched condition) of hair 4 of the third larval abdominal segment is illustrated in Figure 2. In this figure each square represents 25 larvae from a single egg raft. In general, this hair is double (occasionally single or triple) in *pipiens* and single (occasionally double) in *quinquefasciatus.* Individual pure-line specimens cannot be accurately identified by this character but if a sample of 10 or more larvae from a single collection are examined a determination can be safely made.

The effect of hybridization upon hair 4 of the third abdominal segment is similar to that upon DV/D in that the hybrids are intermediate, but differs somewhat in that an overlap with *pipiens* occurs. Backcrossing the hybrid line to *pipiens* results in an almost complete approach to *pipiens,* but with more variability occurring than in pure-line stock.

Backcrossing to *quinquefasciatus* results in a rather typical production of intermediates. As with the DV/D ratio, it appears that a third backcross is needed in the case of *quinquefasciatus* to return the stock to a condition resembling the pure line.

MISCELLANEOUS. In connection with the above two characters, no significant differences could be detected between the two combinations of straight crosses, the eight combinations of first backcrosses, and the four combinations of second backcrosses that were made. Consequently, the data were combined for each of these sets of combinations for use in Figures 1 and 2.

It has been shown by Knight and Abdel Malek (1951) that an average of 1.1 percent of *pipiens* females in the Cairo area are capable of laying eggs without a prior bloodmeal (autogeny). Autogeny has never been demonstrated for *quinquefasciatus.* In view of these facts, it is of interest to note that in the hybridization experiments reported in this paper one autogenous fertile egg raft was obtained. The egg raft resulted from a first backcross of hybrid males to female *pipiens* (Pq ♂ × p ♀). Unfortunately, the larvae resulting from this egg raft did not survive to maturity.

DISCUSSION. It is apparent from the study reported by Barr and Kartman (1951) and from this one that hybrid stocks of *pipiens-quinquefasciatus* will revert in two to three generations to the

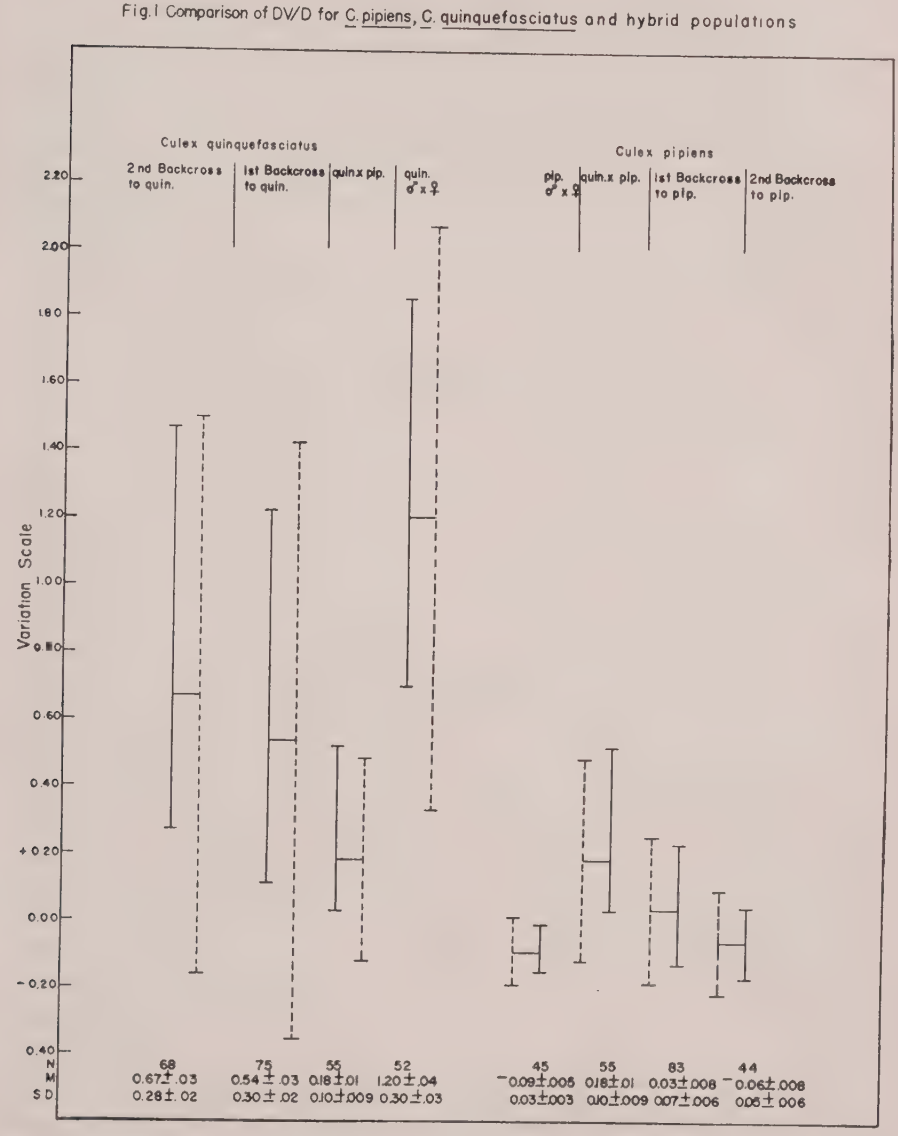

FIG 1. Comparison of DV/D for *C. pipiens, C. quinquefasciatus* and hybrid populations. The solid line indicates the observed range of variation, the cross line the mean, and the dash line the mean plus and minus three standard deviations. The data below these lines present the number of examples measured from each population (N), the means and their standard errors (M), and the standard deviations and their standard errors (S.D.).

parent type if backcrossing is allowed to take place. In this study it was found that reversion to the parent type occurs approximately one generation faster with *pipiens* than it does with *quinquefasciatus*.

On the basis of the data presented here, it is believed possible to determine the parentage of field-collected material by securing egg rafts, rearing them in isolation, and then determining for each raft the DV/D ratio for 10 or more males and the number of branches possessed by hair 4 of abdominal segment III for 25 or more larvae. However, for the most complete accuracy, this procedure should be preceded by a determination of the range and mean for these characters for known pure-line stocks from the general geographic area. Evidence of the importance of this procedure is the fact that Sundararaman (1949) found DV/D for *pipiens* (United States) to be 0.0 to 0.5, and Barr and Kartman (1951) found it to be 0.0 to 0.2. In contrast to this, all *pipiens* examined from Cairo had the DV/D ratio falling in a range of —0.15 to —0.01.

Fig. 2. Hair 4 of third segment of larva of C. pipiens, C. quinquefasciatus and hybrid populations

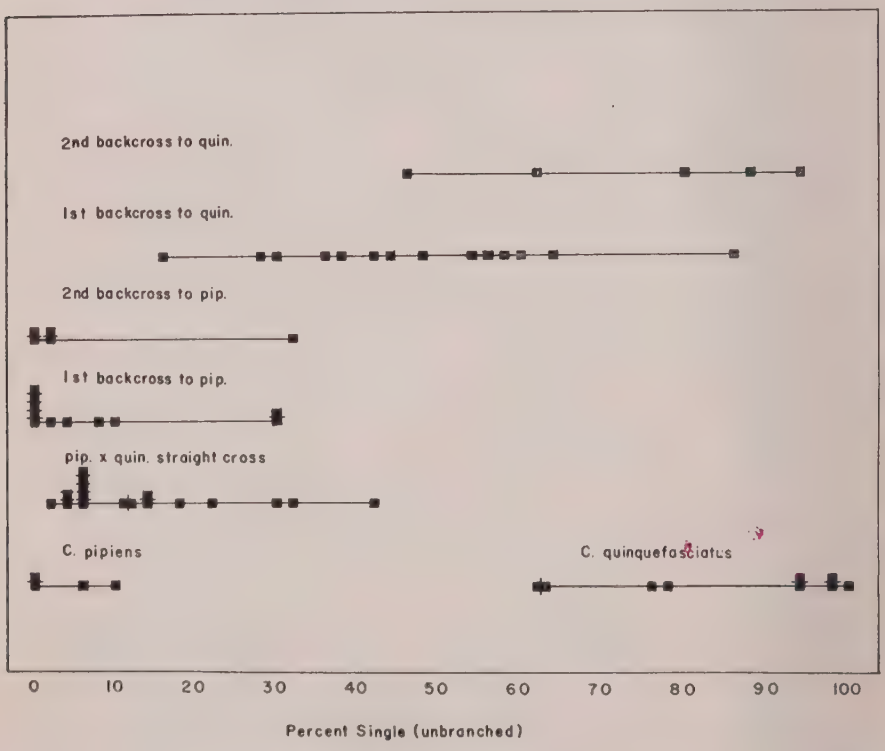

FIG. 2. Hair 4 of third abdominal segment of larva of *C. pipiens, C. quinquefasciatus* and hybrid populations. In this figure each square represents 25 larvae from a single egg raft. Since hair 4 is paired, each square represents the examination of 50 hairs. The position of each square represents the percentage of these 50 hairs that are single.

However, in all three cases the range of variation was distinct from that of *quinquefasciatus*.

A word of caution in connection with the above discussion must be added. Because only a portion of the female *quinquefasciatus* in this colony ever became fertilized, presumably due in part to the small size of the container, an unnatural selective force was in action which may well have decisively colored the results. It is possible that if the adults in the hybridization experiments had been caged in a space sufficiently large to have permitted 100 percent fertilization of the *quinquefasciatus* females, that altogether different results might have occurred. Any future experiments should attempt to remove this possible selective force.

It is a pleasure to express my indebtedness to Mr. Harry Hoogstraal, U. S. Naval Medical Research Unit No. 3, Cairo, Egypt, for the Eritrean *quinquefasciatus* colony. Mr. Sobha Gaber, technician, painstakingly attended the mosquito rearing throughout this project and deserves much credit for his excellent work.

SUMMARY. This study was made to determine the effect of backcrossing upon hybrid stocks of *Culex pipiens* × *Culex quinquefasciatus*. The *pipiens* stock used came from Cairo, Egypt, and the *quinquefasciatus* colony from Asmara, Eritrea. The first backcross was accomplished in all possible combinations. The second backcross was made in four combinations. Two morphological characters, one adult and one larval, were used to evaluate the effects of hybridization. The results indicate that if backcrossing is allowed to take place hybrid stocks of *pipiens* × *quinquefasciatus* will revert in two to three generations to the parent type. This reversion to the parent type occurs approximately one generation faster with *pipiens* than it does with *quinquefasciatus*.

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STUDIES IN TESTING INSECT REPELLENTS [1]

S. KASMAN,[2] L. A. O. ROADHOUSE,[3] AND GEORGE F WRIGHT [4]

The development of synthetic organic chemistry during the past century is due in large part to the development of simple, rapid, and precise chemical analyses. Synthesis proceeds at a rate that is dependent on the application of these methods. However, synthesis of chemicals of biological interest is frequently hindered by the delays and the crudities of some biological assays. In efforts to correlate the functional groups in organic chemicals with their insect-repellent properties, we have encountered such difficulties. For example, the human arm test, in which the forearm covered with 1 gram of repellent is exposed to biting insects (Roadhouse, in preparation), cannot be carried out economically at the rate at which pure chemicals can be synthesized for testing.

The ultimate evaluation of a repellent designed to protect humans against biting insects, especially mosquitoes, must be carried out with human subjects. However, it does not follow that the interim testing, during which the successful repellent is being devised, should be carried out with humans. There are several good reasons why other types of test should be used:

1. Preparation of the 1 gram of unproved repellent required for the human arm test usually entails much more time and expense than preparation of a smaller quantity.

2. The human arm test is time-consuming, since it often requires the services of the test subject during half a day.

3. Individual idiosyncrasy may vitiate the tests unless enough humans are used, in which case the expenditure of candidate repellent becomes inordinately high.

4. Dietary and environmental variations in as complex an animal as the human may cause wide variation in results from individual to individual, and from day to day.

5. Candidate repellents may have unsuspected toxicity.

For several reasons, the use of an olfactometer does not yet satisfy the requirements of a test that would enable a correlation to be made between the results of the test and the chemical groupings so that new repellents might be synthesized. First, it is not a rapid analytical method. Second, it does not take into account the essential function of a repellent as a barrier between the insect and the subject to be protected. It defines only the effect of the repellent vapor, without the surface from which that vapor must arise. Third, it does not define tactile repellency.

The human arm test as it is carried out in the laboratory is deficient as a means of complete evaluation of a repellent, since it does not measure environmental variations such as exposure to sunlight, perspiration, and wind. Because of this deficiency, we believe that it is unnecessary to use humans in the initial laboratory screening tests. Therefore we have sought to use animals that are more easily available for testing purposes, are more uniform, and are expendable for tests with types of substances not previously examined. We have chosen guinea pigs as test animals to ensure reproducibility of results in different laboratories.

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[1] Contribution No. 3070, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada. Studies performed in the laboratories of Science Service, Ottawa, in co-operation with the Defence Research Board, Department of National Defence, Ottawa; and the Department of Chemistry, University of Toronto, Toronto, Canada.

[2] Technical Officer, Defence Research Board, Ottawa, Canada, when these studies were performed.

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Not only are guinea pigs useful for the standardized repellency test, but they can be used also for investigation of their attractiveness to insects through change in diet, and may be sacrificed to evaluate the physiological effects of repellents on the skin. The method outlined herein is for mosquitoes, but may be adapted to other biting insects.

TESTING WITH GUINEA PIGS: It is of prime importance that the animal be kept immobile while a definite, fixed area of its back is exposed to mosquitoes. This immobility has been attained by fitting the guinea pig into a tapered 10-inch length of Visking HS sausage casing [5] in which a hole is cut to expose an even surface of skin. In this slippery enclosure the animal soon learns the futility of trying to escape and rests quietly.

For fitting the animal, a 20-inch calibrating length of casing 4⅛ inches in diameter is folded along one side, so that the narrow end of the flat casing is 1½ inches wide, and a 3:14 taper is made along the length. The fold is secured with Scotch tape. The unfolded edge is calibrated in 1-inch divisions with a wax pencil. Smearing of these markings is prevented by covering them with Scotch tape.

The hair is removed completely from the back and sides of the animal between the shoulders and the rump with an electric clipper fitted with a 0000 blade head. It is important that this clipping be as thorough and as close as possible; however, the skin must not be scarred or scratched in the process. Loose hair is brushed away, and the animal with the legs drawn up and hind end first is placed into the calibrating casing. The animal is then shaken firmly into the tapered calibrating casing (Fig. 1). The center of the circular area to be exposed and the position of the end of the rump are recorded to within 1/10 to ⅕ inch.

The pig is removed and a fresh 10-inch length of casing is laid with its edge even with the markings on the calibrated casing, which has its tapered edge toward the right side of the operator. The right-hand end of the short length of casing is made to overlap the recorded position of the end of the rump by 1 inch. The lower right-hand corner of the short length of casing is then folded to correspond with the taper of the calibrating casing, and is secured to itself with Scotch tape. (If the diagonal crease extends the full 10-inch length of the casing, then it should be abandoned in favor of the next smaller diameter of casing.) A semicircular pattern, 6.68 cm. in diameter (the circular exposure area is 35 sq. cm.), is then placed on the upper, straight edge of the casing with its center coinciding with the recorded position of the area to be exposed, as measured by the calibrating casing. The casing is then cut so as to provide the aperture of 35 sq. cm. Finally a closing fold of ½ inch is made and taped at the narrow end of this 10-inch length of casing; a small triangle is cut out at the lower corner for disposal of urine and feces.

The animal is slipped into the prepared casing in the same position that it was fitted into the calibrating casing, care being taken that its backbone lies along the line of the natural crease of the casing. The pig must be shaken firmly into place; if the casing splits, it may be reclaimed for use by repair with Scotch tape. The guinea pig in the casing is held during the test in one of two troughs constructed from two pieces of cardboard. These pieces are cut as shown in Figs. 4 and 5. The flaps of the larger pieces are folded and stitched at coinciding edges and the seams covered with Scotch tape. The smaller piece of cardboard is then bowed along the long axis and fitted inside this box with its straight end against the rectangular back end of the box; the re-

[5] Visking High-Stretch casing (Visking Ltd., Lindsay, Ont.) is packaged in 200 flat lengths, each 20 inches long. For economy, these lengths are normally cut in half, although the occasional active or large animal may require a 12-inch rather than a 10-inch length. The available ones useful for this test are those 3¼, 3¾, and 4⅛ inches wide. These diameters accommodate animals weighing between 350 and 1000 grams.

entrant shape of the front end of the box thus forms it into a trough, which is stitched and taped into position. These troughs maintain the guinea pig at an angle of 30° from the horizontal position so that the animal is unable to shift position or to climb out of the casing. One of the troughs is kept inside the mosquito cage, and the other serves for repose outside the cage during the period between the exposures to mosquitoes.

FIG. 1. Measuring of guinea pig in calibrating casing.
FIG. 2. Applying drops of repellent to exposed area of skin.
FIG. 3. Guinea pig in completed assembly in testing cage.

The casing-enclosed animal in a trough is treated with 0.05 ml. of repellent from a 0.25-ml. hypodermic syringe equipped with a fine (No. 28) needle. The repellent is distributed in about 10 small drops symmetrically on the exposed area of animal skin (Fig. 2). The drops of repellent are then spread rapidly and evenly with the finger tip; the periphery of the area must be covered slightly underneath the casing in order that the mosquitoes will not find an untreated surface.

The open end of the casing is then covered with a length of women's nylon hose to protect the guinea pig's face and ears from the mosquitoes (while still allowing access of light and air) so as to ensure its repose. The assembly is quickly transferred to the trough inside the mosquito cage (Fig. 3), which contains about 1000 males and females of *Aedes aegypti* (L.) in approximately equal numbers.

An initial 3-minute exposure is then made, and the number of landings and the number of bites involving ingestion of blood are recorded. The animal is then removed to the trough outside the cage, where it remains for 27 minutes until the next exposure. The test is finished when three bites are observed within one, two, or three consecutive 3-minute exposure periods.

The validity of the test obviously depends on the activity of the mosquitoes and the avidity with which the females seek a blood meal. When more accurate evaluation is desired, the guinea pig is exposed without repellent, and the biting rate (30–90 per minute) is determined about one minute after the animal is inserted into the cage. Ordinarily we dispense with this evaluation; instead, the activity of the mosquitoes is judged by the number that land on the treated area but do not bite. A landing rate of 15–35

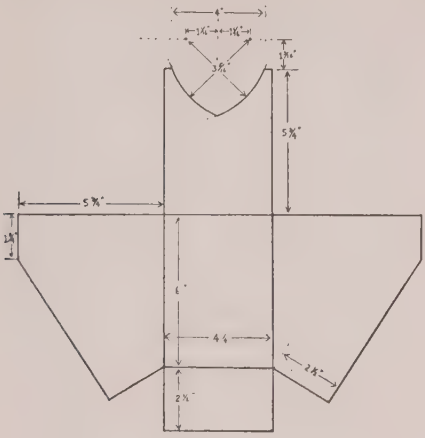

FIG. 4. Diagrammatic pattern of outer part of box for retention of guinea pig in tests of repellents.

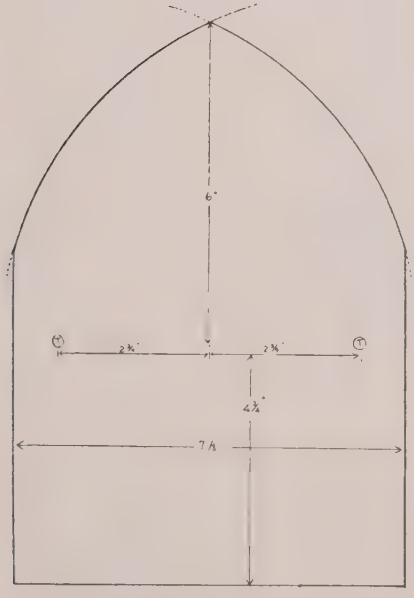

FIG. 5. Diagrammatic pattern of trough of box for retention of guinea pig in tests of repellents.

per minute is considered satisfactory. Only when this rate drops to 10 per minute are the mosquitoes considered to be too sluggish or satiated for reliable results. Until a precise differentiation between vaporous and tactile repellency is desired, this criterion seems satisfactory.

EVALUATION OF REPELLENCY TIME: With mosquitoes, a single bite within the test exposure of 3 minutes is not considered indicative of the breakdown of protection. It may be due to resistance of a single hardy mosquito. On the other hand, the failure of the repellent may become appreciable before the next test period occurs. Consequently the time, *T*, during which the repellent is considered effective is calculated according to the equation

$$T = (30)n + 30/(b + 1)$$

where *n* is the number of 3-minute exposures before a single exposure with at least 3 bites or before successive exposures with at least 3 bites, and *b* is the number of bites that occur during the first exposure that contributes to a total of at least three bites within that or succeeding exposures. During this evaluation, care must be taken not to count a group of mosquitoes all biting in a short line or space. Such behavior is almost certain evidence of uneven distribution of repellent and the test should be repeated. If three bites occur in the first exposure, *T* equals zero.

DETERMINATION OF AMOUNT OF REPELLENT: Since all repellents used in this study are liquids, the amount of repellent is expressed in terms of volume. The variation in time of protection according to the volume of repellent distributed on the guinea pig has been determined for dimethyl phthalate. This was accomplished by applying various volumes of dimethyl phthalate to the exposed area of the guinea pig. Some of the smaller volumes were applied as 10 per cent solutions in 95 per cent ethanol to facilitate even distribution of the substance; larger volumes were applied as the pure liquid. Plotting the repellency times against the

corresponding volumes of dimethyl phthalate used, showed that the relationship was approximately linear up to the 0.05 ml. volume and then it tended to level off. The 0.05 ml. volume gave protection for approximately the same time as in the arm test and is the smallest volume that can be readily applied evenly on the exposed area of the guinea pig.

COMPARISON OF HUMAN ARM WITH GUINEA PIG TEST: More than 100 compounds have been used in a study of the two tests. For many of these the repellency times were too small to afford a valid comparison. The remainder are listed in Table 1, with physical constants given in Table 2 when it has been necessary or feasible to determine them. The evaluation of repellency by the arm test has been reported elsewhere (Roadhouse, in preparation), and the values obtained have been used for comparison when considered reliable. In general, the protection time for guinea pigs is slightly less than for the human arm. This difference is not unexpected in view of the higher body temperature of the small animal (Oppenheimer and Pincussen, 1925, pp. 376–377),

TABLE 1.—Comparison of repellents in human arm and guinea pig tests

Expt. No.	Compound	Boiling point °C	mm.Hg.	Protection time min. Human arm	Guinea pig
G-1	dimethyl phthalate	136.5-138.5	8	200	185
G-2	2-methyl-1-phenyl-2-hydroxy-propanone-1	119-121	11	185	160
G-3	4-phenyl-1,3-dioxane	177-179	104	245	186
G-4	ethyl 2-hydroxydecanoate	110-115	7.5	160	125
G-5	ethyl mandelate	118-120	7	275	300
G-6	benzyl lactate	122-125	7	345	280
G-7	1-phenyl-1-hydroxypropanone-2	115-117	7	335	345
G-66	1-phenyl-2-hydroxypropanone-1	108-110	7	330	225
G-9	1-phenyl-1-methylpropanediol-1,2	ca. 130	7	305	338
G-11	cinnamyl acetate	128	7.5	120	135
G-12	1-phenyl-1,3-diacetoxypropane	153-154	7	5	0
G-14	1-phenylpropanediol-1,3	92-94	7	135	95
G-15	ethyl 2-methoxyphenylacetate	ca. 128	8	105	147
G-16	2-ethylhexanediol-1,3	119.2-120.4	7	200	244
G-17	n-butylacetanilide	128.5-129.0	7	375	375
G-18	dicyclohexylketone	133.0-134.5	8	340	310
G-19	dicyclohexylcarbinol	m.p. 35°		0	0
G-20	saturated solution of G-19 in G-18			187	186
G-22	70% 2-cyclohexylcyclohenanol + 30% 2-phenylcyclohexanol	123.9-128.6	7	345	345
G-23	2-allyl-4-methoxyphenol	127.2-128.0	7	405	370
G-24	2-propenyl-4-methoxyphenol	136.2-140.2	7	400	375
G-25	2-allylhydroquinone dimethyl ether	108-110	7	156	127
G-26	tert-butylhydroquinone dimethyl ether	108.1-110.2	7	0	0
G-27	1-phenyl-2-methylpropanol-2	94-94.5	12	95	65
G-42	ethyl phenoxyacetate	131-133	13	45	75
G-43	1-phenyl-2-methyl-2-methoxy-propanol-1	ca. 125	14	188	160
G-49	geraniol acetate	122-124	16	75	45
G-50	linalyl acetate			5	45
G-52	benzyl glycolate			165	165
G-55	2-phenylcyclohexanol	142-146	15	165	135
G-59	hexahydro-4,4-endomethylene-indanone-5	112	15	35	15
G-63	2,2,4-trimethyl-1-acetoxy-pentanol-3	118-119	15	115	66
G-64	N,N-dicyclohexylimidazolidine	125-126	0.5	460	465
G-68	1,4-diacetoxydecahydronaphthalene	179	16	38	46
G-69	ethyl isopentylacetoacetate	135	16	75	45
G-70	2,2-dimethylpentanediol-1,5	ca. 147	16	0	0
G-71	2,2,4-trimethylpentanediol-1,3	123	16	310	315
T-50	eugenol methyl ether			40	100
T-90	benzyl 2-acetoxydecanoate			98	65
T-91	benzyl 2-acetoxypropionate			105	96
T-104	cinnamyl alcohol			248	225
T-181	1-phenyl-2-methylpropanediol-1,2			98	40
T-187	1-phenyl-2-methylpropanol-1			128	96
T-203	2-N-n-butylaminocyclohexanol			150	128

TABLE 2.—Refractive indices and densities of compounds G–1 to G–18 in Table 1

Expt. No.	Refractive Index*	Density**
G–1	1.5159	——
G–2	1.5314	D $^{24.2}$ 1.023
G–3	1.5288	D $^{25.1}$ 1.110
G–4	1.4372	D $^{25.6}$ 0.928
G–5	1.5141	D $^{24.9}$ 1.114
G–6	1.5147	D $^{24.5}$ 1.116
G–7	1.5356	D $^{25.3}$ 1.102
G–66	1.5361	D $^{22.7}$ 1.100
G–9	1.5361	D $^{25.2}$ 1.062
G–11	1.5389	——
G–12	1.4951	D $^{22.3}$ 1.098
G–14	1.5312	D $^{24.9}$ 1.019
G–15	1.5022	D $^{25.5}$ 1.113
G–16	1.4512	——
G–17	1.5148	D $^{20.5}$ 0.987
G–18	1.4845	D $^{25.3}$ 0.961

* Taken on *D* line at 20° C.
** At degrees Centigrade in comparison with water at 0° C.

since heat is an attractant to mosquitoes. Fig. 6 shows that these data are best described by the equation

$$T_p = T_a - 20$$

where T_p and T_a are protection times in minutes for the guinea pig and arm tests respectively. Though a few of the values differ by as much as 50 minutes, Fig. 6 shows that the majority of the values are included within the terms of this equation.

FATE OF THE APPLIED REPELLENT: A repellent may lose its effectiveness in three ways: it may evaporate, it may be absorbed through the skin, or it may be destroyed on the skin. These possible modes of loss have been studied in the guinea pig test.

The approximate rate of evaporation of dimethyl phthalate was determined by evaporation from filter paper. Whatman No. 50 (50 mm.) papers were suspended

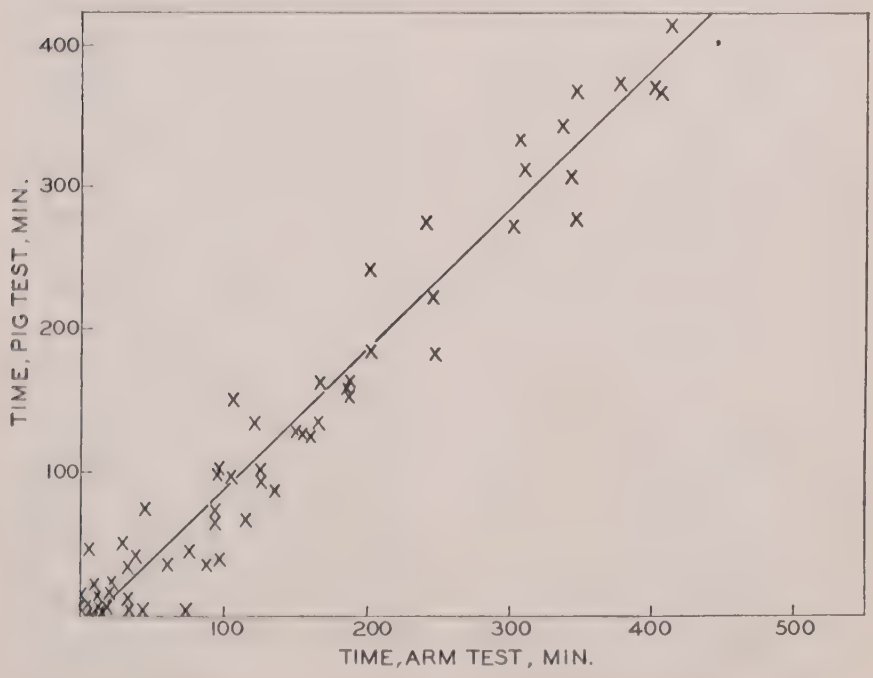

FIG. 6. Repellency times in guinea pig and human arm tests of various repellent compounds.

overnight from fine piano-wire hooks in an oven at 37° C. They were then allowed to cool to room temperature and weighed. Various amounts of dimethyl phthalate were then applied near the hooks and allowed to soak into the paper. The discs were reweighed, replaced in the oven, and withdrawn at intervals for reweighing to determine loss by evaporation. Table 3 summarizes the averages of five concurrent determinations.

The rate of evaporation is approximately linear for the first 300 minutes, indicating that it depends on the area of the surface and not on the quantity of repellent present. The data may be expressed by the equation

Weight lost by evaporation (in milligrams) = 0.0174 T (in minutes)

where the proportionality constant is a modulus of surface area, vapor pressure of dimethyl phthalate at 37° C., and adventitious factors such as amount of air circulated past the surfaces, structure of filter paper fiber, and room temperature during weighing periods. Despite these factors, which should tend to increase the evaporation rate by comparison with that occurring from the skin, it may be seen (G-1, Table 1) that the rate of loss by evaporation is much lower than the loss of protective action by dimethyl phthalate on the back of the guinea pig or on the human arm. Table 3 indicates that the loss by evaporation from filter paper is

$$\frac{(22.3 - 17.7) \text{ mg.}}{(265 \text{ min.})\ (3.14 \times 2.5^2 \times 2 \text{ sq. cm.})} = 0.00044 \text{ mg. (min./sq. cm.)}$$

whereas the weight of dimethyl phthalate applied per square centimeter on the back of the guinea pig is

$$\frac{1.19 \text{ (density of DMP)} \times 0.05 \text{ ml.}}{35 \text{ cm.}^2 \text{ (area of skin)}} = 1.7 \text{ mg./cm.}^2$$

On the basis of evaporation, then, dimethyl phthalate should give protection for 1.7/0.00044, or 3900, minutes. Since this is about 20 times the observed duration of repellency, the loss of protection must therefore be due to hydrolysis of the ester or to absorption through the skin.

TABLE 3.—Evaporation rates of dimethyl phthalate

Time min.	Weight of dimethyl phthalate mg.	Loss %
0	22.30	0
107	20.67	7.2
190	18.92	15.1
265	17.70	20.6
350	17.24	22.6
1397	3.69	93.4

To evaluate these losses, the normal benzoic acid content in the urine of a guinea pig, collected during 24 hours in a metabolism cage, was determined. Then 0.25 ml. (0.277 g.) of 1-phenyl-2-hydroxypropanone-1 (G-66, Table 1) was placed on the shaved back of the guinea pig, and the urine was collected during the next two 24-hour periods. The urine collected during one of the periods was made alkaline with 10 ml. of 0.4 N aqueous sodium hydroxide, and then warmed for 2 hours at 85° C. to hydrolyze any hippuric acid that may have been present. The hydrolyzate was filtered, acidified with a 4-ml. excess of 7 per cent hydrochloric acid, and then steam-distilled to collect 400 ml. of distillate. This distillate was extracted four times with a total of 60 ml. of chloroform. Evaporation of the chloroform left negligible residue from the samples collected during the 24 hours before application of repellent and during the second 24-hour period after its application. On the other hand, the residue from the urine sample collected during the 24-hour period after application of repellent was appreciable. It was sublimed at 750 mm. to yield 10 mg. melting at 112–118° C. This sublimate was proved by mixture melting point to be benzoic acid after it was resublimed to melt at 119–121° C. A 10-mg. yield represents 4.5 per cent of that theoretically available from the oxidation of 1-phenyl-2-hydroxypropanone-1. If this benzoic acid is the metabolic product from the ketone (G-66,

Table 1), absorption of repellent through the skin is a significant factor of loss.

INFRA-RED SPECTRA OF INSECT REPELLENTS: It has been suggested (Miles and Beck, 1947) that a substance is odorous because its vapor passing among the olfactory hairs selectively absorbs in the infra-red spectral region so as to disturb the thermal equilibrium in the olfactory region. This disturbance is thought by Miles and Beck to initiate olfaction.

Since repellency must in part be related to the olfactory sense, we have partially tested this hypothesis by examination of the infra-red spectra (25μ—16μ) of the substances listed in Table 1 for which boiling point, refractive index, and density are reported. The Baird spectrograph used by Dr. Charles Hubely of the Defense Research Board (to whom we are indebted for these spectra) is not equipped for study of vapors, so that it must be assumed that spectra of the liquids are indicative of those in the vapor state. With this limitation we can affirm that no absorption band is present among these substances that is common to them all, or that is related to intensity to the observed insect repellencies of the compounds.

SUMMARY: A method of screening compounds as insect repellents with guinea pigs as the test animals is described. The repellency values obtained with the guinea pig are approximately the same as those obtained from human arm tests. The advantages of this technique are that a smaller quantity of the candidate material is required for each test and toxicity to the host is not a major consideration. In tests of dimethyl phthalate with guinea pigs more repellent was lost by absorption through the skin than by evaporation. Infra-red spectrographic analyses of several compounds in liquid form were of no value in predicting their effectiveness as insect repellents.

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MOSQUITO SURVEY OF GUAM

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Since Hawaii became a crossroads for planes as well as the many ships of the Pacific, the island of Guam is only twelve hours away from our Territory. Hawaii is only nine hours by plane to California. Faster transportation increases the danger of the spread of diseases as well as of the vectors of diseases from the Pacific region to our West Coast.

A survey trip was taken from July 11 to August 18, 1952 to Guam and the Trust Territory.

On the way to Guam, brief stops were made on Midway and Wake Island. Both of these islands were once infested with mosquitoes until Hawaii's mosquito control personnel started a clean-up campaign for the Civil Aeronautics Administration.

No mosquito was found during my stay on these stepping stones in the Pacific.

Guam constitutes our first line of defense in the screening of diseases and disease vectors from the Orient. Unfortunately, the island suffered so much from the destruction of the Pacific war that reconstruction has to be undertaken on a massive scale. The capital city of Agana was practically flattened to the ground and the population there was scattered. A new and better city is in the process of being built and the health program is gradually being enlarged.

A mosquito-borne disease from the Orient, Japanese B encephalitis, apparently overcame the ocean barrier of 2,000 miles and broke out as an epidemic on Guam in 1947. According to Dr. W. M. Hammon (1949), this highly fatal form of sleeping sickness has leaped from Japan to Guam.

Large epidemics of dengue have occurred on Guam. The last outbreak in 1944 resulted in several thousand cases among military personnel.

Along with the apparent introduction of a new mosquito-borne disease to Guam during the last war, two new species of mosquitoes which are potential vectors of epidemic diseases were introduced as well.

The Central Pacific-Micronesian area has always been considered an *Anopheles* malaria free area, until the *Anopheles subpictus indefinitus* was found by the Army to have established itself in the southern part of Guam by early 1948, according to Hull (1952). Within a year, it has spread throughout the island, according to a survey by Reeves and Rudnick (1951). This mosquito was able to spread so fast because it has a wide range of breeding places, from highly saline water along the beaches to many types of ground water. I collected the larvae from puddles, pools and hoof prints. I found them breeding in abundance in low lying land of empty lots in the midst of built-up sections.

Anopheles subpictus indefinitus prefers feeding on animal blood. However, if domestic animals are not available as sources of blood, it will attack man. It has been incriminated as the main vector in an epidemic of malaria in Celebes. It is a potential vector of the disease on Guam, especially with the recent importation of large numbers of laborers from malaria endemic areas to the island.

The second new mosquito introduced into Guam during the war was *Aedes albopictus*. It was first found in Guam in 1944 by Lt. Comdr. A. B. Weathersby of the Marines, according to Hull (1952). It was reported by Reeves and Rudnick (1951) to be widely distributed in 1948 except on the southern end of the island. Since then, it has spread to the southern end as well.

During my survey, I examined the mosquito larvae in 92 containers from various parts of the island. *Aedes albopictus* larvae were found in 73 per cent of them, *Culex quinquefasciatus* in 25 per cent and *Aedes guamensis* in the remaining two per cent. The need for storing rainwater collected from roofs in 50-gallon drums and various other storage receptacles at many of the houses in the rural districts increases the number of breeding places available to *Aedes albopictus*.

Since its recent introduction into the island, *Aedes albopticus* has become so abundant and widespread that it is becoming a serious pest as well as a health menace. It is a potential vector of dengue, yellow fever, and Japanese B encephalitis.

Aedes aegypti has practically been exterminated from Guam by the anti-dengue campaign of 1944–45. Reeves and Rudnick (1951) did not find any in 1948–49, nor did Hull (1952) of the Navy who made a survey in 1951. None were seen during my survey. Our experiences in Honolulu also indicate the relative ease with which *Aedes aegypti* can be eradicated. We have failed to find any of this strictly domestic mosquito in Honolulu for the last two years. It is quite a different matter with *Aedes albopictus*, which has a much wider range of breeding places and is more adaptable to environmental changes. This more versatile species has replaced *Aedes aegypti* on

Guam, as it has already done in Honolulu. It is doubtless breeding in greater abundance there, with increased danger as a potential vector of diseases.

Culex annulirostris marianae was found breeding in ground pools together with *Culex quinquefasciatus* at the village of Piti.

Aedes vexans nocturnus was found in the water of a puddle at Umatac.

Larvae of *Aedes guamensis* were found in water from the leaf base of Pandanus plants as well as in a coconut tree hole at Tumon Bay.

The adults of *Aedes pandani* are fierce biters when one is in the vicinity of the Pandanus. Bohart and Ingram (1946) reported their breeding place in the water of the leaf axils of Pandanus. Their flight range appeared to be rather short as I was not bothered by them at Tumon Bay until I was within about 100 yards of their breeding places. They then attacked in numbers, so that I could hardly collect them fast enough from my arms.

Other species reported for Guam which I failed to collect during my short survey are *Culex sitiens* and *Culex littoralis,* reported to be breeding in brackish water along the shore. *Aedes oakleyi* was reported as a rare species breeding in tree holes and containers.

There are altogether eleven species of mosquitoes reported for Guam by Reeves and Rudnick (1951). Seven of them were collected during my brief survey.

Mosquito control in Guam is being carried on by Dr. C. J. Wynberg, Chief of Public Health in Guam. Thomas Curran, Sanitarian, is in charge of field work.

I was informed that the mosquito control program for Guam will be expanded with a team of about fifteen men in the field staff. They will receive laboratory training from George D. Peterson, Jr., who is Entomologist with the Guam Department of Agriculture. My survey in Guam was carried out with the kind cooperation of both Peterson and Curran.

We need to be on our guard in Hawaii against the possible introduction of Japanese B encephalitis since two of our three local mosquitoes, *Culex quinquefasciatus* and *Aedes albopictus* are potential vectors. We are also on our guard against the further migration of *Anopheles subpictus indefinitus* to our part of the Pacific. In these days of fast air transportation, distant areas become close neighbors, and our health is linked to the rest of the Pacific region.

Hawaii is the last screen through which mosquitoes and mosquito-borne diseases from the Orient as well as the South Pacific may continue on their way to the West Coast. We hope to do a good job on our home base so that Hawaii may do her part in protecting the rest of the country. Furthermore, we are doing what we can to promote mosquito control in the rest of the Pacific region.

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WEATHER AND MOSQUITO CONTROL ACTIVITIES*

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Until about two months ago, mosquito control, to me, would have meant using a $1.98 aerosol bomb to kill mosquitoes when they were numerous, a 10¢ flyswatter to kill unsuspecting ones which were resting on a hard surface, or one's palm against that part of the anatomy into which a mosquito was drilling. Since then I have learned of the many projects and fine work done by mosquito control personnel throughout the country and in many parts of the world. The remarks which follow will necessarily be those of a layman, but one who has had experience in handling collectives of data in another field. It is hoped that the suggestions offered can be used, with proper modifications, to increase entomological knowledge and benefit mosquito control work.

About two months ago the Air Surgeon of the Strategic Air Command sent a request for information to the Directorate of Climatology of the USAF Air Weather Service. The Air Surgeon wanted specific weather data to be used in planning a mosquito control program at MacDill Air Force Base, Tampa, Florida. A check with entomologists, primarily those in the Washington, D.C. area, indicated that the information requested would not be of sufficient practical value to warrant the expenditure of time and effort necessary to analyze the data along the lines suggested by the Air Surgeon. It is encouraging to note, however, that individuals are becoming increasingly cognizant of a weather problem, and are trying to solve it, even if their approaches to the solution are not always what the meteorologists would recommend.

An attempt was then made to ascertain from entomologists the effects of various weather elements on mosquito activity. Most of the entomologists did not attempt to estimate the temperatures, wind speeds, etc., which would adversely affect mosquitoes. Those who gave estimates (for salt-marsh mosquitoes, in this case) differed widely enough among themselves to preclude the use of this subjective information. It seemed that quantitative data were needed.

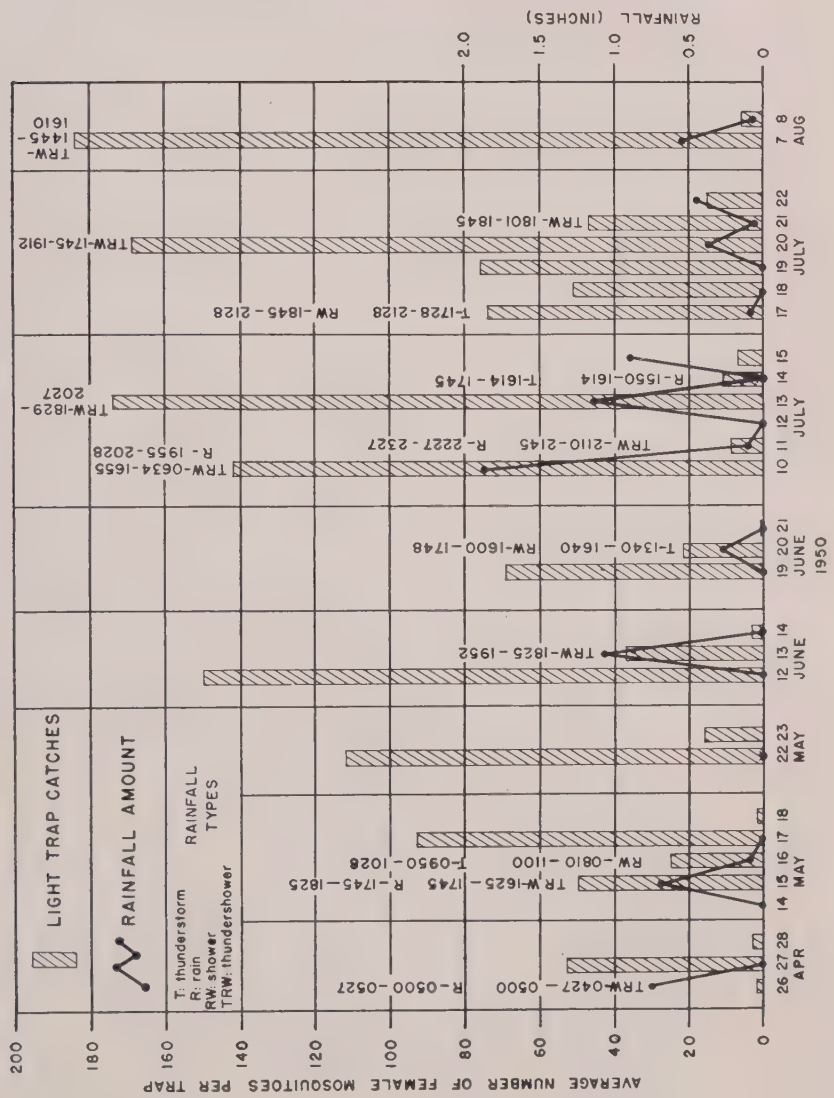
A search of the mosquito literature was then undertaken with the guidance of entomologists, who suggested sources which might yield information on the effects of weather on mosquito activity. Weather was often mentioned as an important factor in mosquito control work, but further consideration of this factor was lacking. Those few studies in which it was actually attempted to use weather left much to be desired from the meteorological standpoint.

Light trap catch data for MacDill Air Force Base were obtained for 1950, 1951, and 1952, together with weather records for the same period. An examination of the data showed that a varying number of traps were operated from one day to another, and that there were numerous gaps in the record. It was quite unusual to have reports for more than 10 consecutive days. The data, however, were painstakingly tabulated by species and by sex.

An analysis of the temperature data for the three years showed no apparent relationship between temperatures and mosquito activity and led to the conclusion that, at MacDill, the temperatures were almost always sufficiently high to be no deterrent to mosquitoes during the periods for which entomological data were available. There were very few mosquito data for the winter months.

Rainfall amounts were then plotted, by

* The views expressed in this article are those of the author and should not be construed to reflect the official opinions of the United States Air Force, the Air Weather Service, or any components thereof.


RAINFALL AND MOSQUITO ACTIVITY AT MACDILL AFB, FLORIDA
AVERAGE NUMBER OF FEMALE MOSQUITOES PER TRAP
RAINFALL (INCHES)
LIGHT TRAP CATCHES
RAINFALL AMOUNT
RAINFALL TYPES
T: thunderstorm
R: rain
RW: shower
TRW: thundershower
TRW-0427 - 0500
R-0500 -0527
TRW-1625 - 1745
R-1745 - 1825
T-0950 - 1028
RW-0810 - 1100
TRW-1825 - 1952
T-1340 - 1640
RW-1600 - 1748
TRW-0634-1655
R - 1955-2028
TRW-1829 - 2027
TRW-2110 - 2145
R-2227 - 2327
R-1550-1614
T-1614 - 1745
T-1728-2128
RW-1845 - 2128
TRW-1745-1912
TRW-1801-1845
TRW-1445 - 1610
26 27 28 APR
14 15 16 17 18 MAY
22 23 MAY
12 13 14 JUNE
19 20 21 JUNE 1950
10 11 12 13 14 15 JULY
17 18 19 20 21 22 JULY
7 8 AUG

day, on a graph with daily mosquito catches. There appeared to be an inverse relationship between the occurrence of rain and the occurrence of mosquitoes. The hours during which it rained (based on a 24-hour clock) were entered on the graph and the relationship was brought out more clearly. It should be recognized that the mosquito data shown for a particular day are taken from the previous evening through the morning of that day, while the rainfall data apply to that civil day. Of course, other factors, such as adulticiding, winds, etc., could have accounted for a decrease in the number of mosquitoes caught from one day to the next, but it seems more than a coincidence that rain in the late afternoon or night occurred in so many cases. The cases shown in the accompanying figure were taken chronologically and include those with marked variation in mosquito activity. This general information probably comes as no surprise to personnel in mosquito control work; however, it represents, in this case, a rapid preliminary attempt by a non-entomologist to quantitatively relate mosquito activity to a weather element. I am sure that, with adequate entomological data, some degree of success along these lines can be achieved. Weather data are generally excellent for such purposes.

Those phases of mosquito control activities which, it seems, should be examined more closely with a view toward their improvement are the ones involving data collection and analysis. Information on these subjects was obtained in lengthy conversations with many entomologists. First there is the non-standardization of instruments, light traps in this case. The fact that lights of differing intensities and fans of differing capacities are used makes comparisons of light trap catches invalid, except in those cases where lights and fans are uniform. It appears that much time, effort, and money are being expended in collecting and identifying mosquitoes caught in traps, and compiling the data. A sufficiently valid explanation as to why this is so large a part of the entire program has not yet, in the opinion of the author, been advanced by entomologists because, considering the non-standardized instruments with which these samples were taken, the data are of such limited use. Of course, it is necessary to do a certain amount of taxonomic work to identify possible disease vectors. However, would some of this effort not be more profitably utilized in a research program? Also, although weather is admittedly an important factor, no systematic attempt has been made to use it as an ally in a mosquito control program. It seems that even weather forecasts are not always obtained in advance of scheduling a spraying operation. One mosquito control man stated that he checked the prevailing winds. He was unable to answer the question, "Why?"

It is felt that a line of research on the ecology of the mosquito, with the aim of making a control program as effective as possible, should be undertaken. An attempt should be made to learn, in quantitative terms, the effects of individual weather elements and combinations of weather elements on mosquito activity. In the absence of long, standardized records of mosquito activity, laboratory experimentation is suggested as the fastest method to achieve this goal. To determine the effects of temperature, relative humidity, illumination, etc., on mosquitoes, it is suggested that use be made of a "climatic chamber"—the size to be determined by the entomologist on the basis of his needs and his budget—in which these factors could be varied at will. It has been mentioned that, not having unlimited space in which to fly, the mosquito might be affected psychologically and might not react normally. Assuming this to be true, why could this device not be used to study the effects of these factors on eggs and to study the absolute ranges of tolerance of adults, larvae, and eggs of the various species?

To study the effects of wind speeds on mosquitoes, it is suggested that a modified wind tunnel be used. A cage divided into two parts could be constructed, with a cylinder connecting them in such a manner that passage through the cylinder

would be necessary to go from one part of the cage to the other. A device for moving the air through the cylinder at controlled speeds would convert it into a miniature wind tunnel. Mosquitoes could then be placed in one part of the cage, perhaps together with a repellent, and an attractant in the other part of the cage. In any event, the entomologist would provide the maximum stimulus for the mosquito to fly from one part of the cage to the other, and wind speeds through the tunnel would be increased to the point at which the mosquitoes could no longer make the flight, thus determining the maximum wind against which a mosquito will fly.

In order to have comparable data in this field it would be necessary to standardize all collection devices. Observations should be taken as often as practicable, but at least once a day, so that an attempt could be made to relate mosquito activity to weather or other forecastable factors selected by the entomologist.

Meteorology can be used by the entomologist in planning and executing his spraying operations. Research might reveal the size and concentration of drops of insecticidal spray which are most effective in killing mosquitoes. Studies of this type, relating weather conditions to chemical warfare operations, in which optimum dispersion of smoke, gases, and spray is required, have been done many times. Other research tailored to the unique needs of mosquito control personnel might be undertaken in cooperation with Meteorology Departments of State Universities and interested governmental agencies.

To recapitulate:

1. The entomologist, with the help of the meteorologist, should attempt to relate mosquito activity to forecastable weather factors.

2. The entomologist, through continuing surveys, would know the age and composition of the adult mosquito population in his area, and also the stages of the larvae in the breeding grounds affecting his area.

3. The entomologist, knowing the aforementioned items, could interpret weather forecasts slanted toward his needs in planning his day-to-day control operations, with the aim of modifying the operation to his financial advantage.

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ARTICLES

BETTER RESULTS WITH MOSQUITO LIGHT TRAPS THROUGH STANDARDIZING MECHANICAL PERFORMANCE [1]

THOMAS D. MULHERN [2]

A great deal of effort has been put forth over the years by many workers in developing methods of measuring mosquito populations in an effort to satisfy the obvious need for accurate representative measures of the prevalence or density of the larval and adult forms. The methods now in use fall in several categories: 1. *Egg counts,* on the water surface, or in soil. 2. *Larval counts,* by the dipper method, by netting, by drawing all the water from the breeding source into a suitable vessel for a complete count, or by the "plastic sleeve" method. 3. *Adult counts,* by human operators including biting collections, aspirator collections, net sweepings, flag counts, counts in resting stations, or counts in animal-baited traps. 4. *Mechanical trap collections* made as a means of sampling the mosquito populations which are present in areas where they may constitute human annoyance.

All of the methods which depend upon human skill and training are correspondingly subject to wide variations. Even the same person will obtain widely varying results over time. Although very definite procedures have been suggested for guiding hand-collecting techniques, there still are no universally accepted standards for hand collecting.

The literature cited to accompany this paper sets forth in considerable detail a full historical account of the development and evolution of the trap which is presently in wide use among mosquito control and research agencies.

As early as 1927, intensive research was undertaken to develop a mechanical device to measure the prevalence of mosquitoes on the wing in communities where they were causing human annoyance (1). The trap was designed to serve as a more uniform collector than the human, and was intended to replace "biting" collections. A number of experimental traps were built and tested. By 1932, the trap known as the New Jersey Mosquito Light Trap had evolved. This trap with relatively few changes has been widely used with good results. There have, however, been some disappointing reports of its performance.

Other users have compared it against biting collections (3, 4, 5), coming to the conclusion that it very adequately represented the prevalence of the mosquitoes which were present in the area and causing human annoyance. In seeking an explanation, reports of variance in results with light traps were investigated whenever possible. It soon became apparent that some users were not operating the mechanical traps in the manner which had been intended, so in 1942 a circular describing the trap and its method of use was prepared (7).

It had frequently been found that the fans and motors with which the traps were equipped had, through lack of adequate maintenance or through damage suffered in operation or handling, lost their ability to move a sufficient quantity of air to enable them to catch an adequate sample of the mosquitoes on the wing. The shortage of mechanical items which was brought about by the demands for war material greatly intensified this problem,

[1] Paper presented before Annual Meeting of the American Mosquito Control Association, Salt Lake City, Utah, March, 1952.

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for old traps with badly worn motors continued in service, while the inability to get the motors which were originally specified often resulted in the substitution of substandard motors and fans. There are today a wide variety of electric motors powering the traps which are in operation, and their air-sampling ability varies greatly. This is very important, for the ability of the trap to catch mosquitoes is dependent to a large degree upon the rate at which air flows through the trap. As early as 1937, the New York City Health Department had a number of traps built, employing high capacity exhaust fans instead of standard fans. These were reported to catch 97% more mosquitoes than old traps operated at the test locations over an entire season. Unfortunately, we have no accurate record of the volume of air which was actually moved by these fans. It is interesting to note that "the relative abundance of the various species in the total catch was found to be quite similar for the new and the old traps; this was true also of the proportion of male to female mosquitoes caught" (4).

Our own experiences led us to the conclusion that not nearly enough attention had been paid to the mechanical performance of the light traps, while the numbers in use had tremendously increased during the war years. Therefore, in 1948 a report was prepared describing a measuring instrument to determine accurately the displacement of air and consequently, the mechanical efficiency of the New Jersey Mosquito Trap (10). This paper has evidently escaped the attention of many of the users of light traps, for there are still in operation many traps which are mechanically sub-standard.

A search of the available sources of supply was made in an attempt to find a more suitable and more durable motor and fan which would require less maintenance and be subject to less variations in operation. A heavy duty type motor and fan with a completely sealed enclosed case was located * and used to power a new trap. These motors were originally designed for refrigerators and other heavy duty service and are built with an enclosed pool of oil for lubrication purposes, so they need never be re-oiled throughout their life period. Since the motor case is completely enclosed, with no openings for ventilation such as were present in most of the other motors used, there is no opportunity for dirt, dust and insects to penetrate to the interior of the motor to interfere with its operation. The fans are 8¾" in diameter, thereby requiring a 10"-diameter trap tube, compared with the 9"-diameter tubes used to accommodate the 8" fans originally used.

The trap has been re-designed to accommodate the more durable motor referred to and at the same time, consideration has been given to the other mechanical features which interfered to some extent with the normal performance of the traps. The new "American" model is shown in fig. 1.

Some of the changes may be enumerated as follows:

1. The ¼" wire mesh screen has been moved from its original position over the mouth of the trap tube to a new position around the tube and top supports, in which position it not only excludes large insects but also prevents birds from building their nests in the space between the top of the tube and the hood.

2. The motor is suspended by a three-point support instead of a one-point support which was originally specified.

3. Instead of having a rigid hanging bracket above the hood of the trap, a chain has been substituted. This change permits the hood to be "nested" when removed from the traps for storage or transportation purposes.

4. A new method of fastening the interior funnel-shaped screen has been devised. This facilitates removal for cleaning or maintenance purposes.

5. A hole in the cyanide jar top at the apex of the interior funnel-shaped screen has been enlarged. This change prevents clogging of the interior screen at this point.

6. The trap tube has been lengthened to

* G.E. #3K967—8¾" blades, W. W. Graniger Inc., San Francisco, Calif., & Newark, N. J.

FIG. 1. "American" Model Mosquito Light Trap and principal parts: Fan, interior screen, cyanide jar, and carton for storing collected insects.

permit the complete elimination of legs. This change allows the traps to be stored in a much smaller space and generally facilitates the handling of them.

7. Two holes are drilled in one side of each trap at a standard spacing to facilitate mounting the traps upon standard brackets.

8. The wiring of the trap is better insulated to reduce the likelihood of electrical difficulties.

Preliminary testing of the new design trap has shown that it has an air moving

capacity of 450–500 cu. ft./minute. Measurements of 25 of the old, non-standard traps ranged from 67 to 287 cu. ft./minute.

Improved mechanical performance of these traps appears to be assured and we may anticipate that with it more reliable collecting results may be achieved. The preliminary field tests have shown collections substantially above those taken with old traps. In due course of time it should be possible to calibrate its performance in collecting mosquitoes against the old standard trap so as to work out conversion factors which will permit the comparing of records taken with the old traps against this new light trap. It is strongly recommended that wherever light traps are used for critical collecting purposes, a condition of the experiment be the frequent measurement of the rate of air movement through the trap and that this air rating be recorded, together with the records of the conditions under which the trap was operating.

Many users of light traps have contributed information which has been considered and has contributed to the development of this new model. To them I extend my appreciation, and particularly to Joseph Tausta of New Jersey, who has offered a great many suggestions for changes which contribute to ease of servicing, and to James Holten of California, who constructed the new traps which we are now testing and which are here described.

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A LIGHT, PNEUMATIC SPRAYER FOR INSTALLATION ON VEHICLES [1]

C. N. HUSMAN [2, 3]

U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

During the last few years several insecticide dispensers have been developed for use on vehicles. Most of this equipment has employed the heat and pressure of the exhaust to disperse the insecticide as a smoke or fog. Some types of exhaust units have been effective in the control of mosquitoes and flies over small areas, but none is capable of dispersing a sufficient volume of fog for adequate coverage of large areas. More important, all of them are injurious to the vehicles on which they are installed. With some types the motor must be raced to produce adequate heat and volume of exhaust, and with others the installation results in back-pressure on the manifold of the engine.

A sprayer that overcomes the most serious faults of the exhaust-type units has been developed at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine. Driven by a V-belt operating on a V-pulley attached to the regular generator pulley, it is capable of delivering insecticide solutions and emulsions at volumes up to 40 gallons per hour. Small, light-weight, and adjustable to fine or coarse sprays, it is adaptable to most types of residual treatment or space spraying in buildings, as well as for outdoor areas.

CONSTRUCTION: Compressor.—A vane-type air compressor was selected in preference to other types because of its lighter weight and greater air volume at low pressure. This type of compressor also produces a uniform pressure, thus eliminating the need for an air tank. It is equipped with a 3½-inch A-section V-pulley and a 3/16-inch brass rod, which is bolted to the side of the compressor to guide the belt. Four 5/16-inch holes are drilled in the base for mounting it on the platform, and the extended legs are cut off. This unit is driven by a 28-inch A-section V-belt. A ¼-inch nipple, ¼-inch elbow, and ¼- by ⅜-inch brass hose coupling are screwed into the air outlet side of the unit. An oil-resistant rubber hose ⅜ inch by 10 feet is clamped onto the hose coupling and extends from the compressor to the regulator valve on the tank in the rear end of the vehicle. A ⅜-inch street elbow, one ⅜- by 2-inch nipple, one ⅜-inch elbow, and one ⅜-inch close nipple are installed in the air breather line making it possible to lower the intake air breather. One ⅜-inch close nipple with a ⅜-inch elbow is screwed into the breather unit for the attachment of the oiler.

Mounting Bracket for Compressor.—The mounting bracket is constructed of 1½- by 1½- by ⅛-inch angle iron, 9 inches in length. A piece large enough to allow a 98° bend is cut out 5 inches from the end, and the joint of the bracket is welded. Two ½-inch holes are drilled for mounting on the cylinder head studs. A 4- by 4½- by 5- by ⅛-inch iron plate is welded to the sides of the angle iron and half of a 4-inch hinge is welded to it.

Air-Compressor Platform.—The air-compressor platform, an iron plate 7¾ by 4 by ⅛ inch with four 5/16 inch holes drilled for mounting the compressor, is welded to the other half of the hinge. This platform is hinged to the mounting bracket, to make

[1] Paper presented before Annual Meeting of the American Mosquito Control Association, Salt Lake City, Utah, March, 1952.

[2] This work was conducted under funds allotted by the Department of the Army to the Bureau of Entomology and Plant Quarantine.

[3] The writer acknowledges the assistance of W. V. King and W. C. McDuffie, under whose supervision this work was done, and also of other members of the Orlando, Fla., laboratory who assisted in the construction and testing of this sprayer.

it possible to engage or disengage the air compressor unit by means of a control cable.

Control Cable for Compressor.—A 6-foot flexible cable, held in position by clamping to the cylinder-head bolt, is connected through a spring to the air compressor for maintaining proper tension on the drive belt.

Power Take-Off.—The generator pulley for power take-off is a standard jeep pulley with a 5-inch A-section V-pulley welded to the flat portion and to the side of the V-pulley which drives the generator.

Insecticide Supply Tank.—The supply tank is constructed from a 5-gallon government-issue auxiliary gas can, placed in the rear compartment of the vehicle. The fluid supply line is a standpipe ⅛ by 18 inches, extending from the top of the tank to within ¼ inch of the bottom. It is held in place by a threaded ¼-inch sleeve welded into the top of the tank. A ¼-inch line strainer is connected to the top end of the standpipe by a ¼-inch elbow and a ¼- by 1½-inch nipple. A ¼- by ⅜-inch hose coupling is screwed into the end of the strainer, and a ⅜-inch hose is clamped to it.

Regulator Bypass Valve and Gage.—The regulator bypass valve and the liquid-pressure gage are connected by two ¼-inch close nipples to a ¼-inch tee which is mounted on top of the tank by means of a ¼-inch (i.d.) threaded sleeve welded into the tank. The valve controls the air pressure in the supply tank, which in turn governs the rate of liquid flow to the nozzles. A ¼-inch cross equipped with two ⅜-inch hose couplings is screwed onto the regulator for attachment of the rubber hose air lines, which are held in place by clamps.

Spray Boom.—The spray boom consists of two ⅛-inch pipes welded together, one 22 and the other 19 inches long. The liquid line is 22 inches long and is offset 3 inches at one end for the installation of the liquid shut-off valve and hose coupling, and 4 inches at the other end for the ⅛-inch pipe coupling for attaching the nozzles. The air line is 19 inches long with threaded ends for nozzle and hose couplings. Two ⅜-inch by 15-foot oil-resistant hoses, one for air and the other for liquid, are used. They are held in place by hose clamps.

Nozzles.—The nozzle head consists of six pneumatic nozzles connected by means of two ¼- by 24-inch pieces of copper tubing; ¼- by ⅛-inch brass fittings connect the nozzles to the tubing and the tubing to the boom. A No. 30 set-up (Nos. 40100 fluid and 120–6–35–60 air nozzles) is used when very small particle sizes are required. When larger particles are desired for residue spraying, the mist nozzles can be removed and replaced by others (set-up No. 29, Nos. 60100 fluid and 140–6–52–70 air nozzles) which will produce a coarser spray.

The entire unit, including air compressor, brackets, tank, hoses, boom, and nozzles weighs approximately 50 pounds.

INSTALLATION ON THE VEHICLE. The oil filter of the vehicle is removed from its position above the generator and mounted on the inside of the left front fender. This is done by using the same bracket, with an additional 7/16-inch hole drilled to fit the bracket on the two left front head bolts. The oil line from the pressure system will be long enough, but the return oil line will have to be replaced with a longer hose. This change in location does not impair the function of the filter.

The air compressor is bolted on a platform, which is held in place by a bracket bolted to the cylinder head of the engine just above the generator (figure 1). The compressor is operated off the generator drive by means of a V-belt; a V-pulley is welded to the generator pulley to accommodate the V-belt. A lock-type flexible control cable is mounted on the instrument panel of the vehicle so that the driver can engage or disengage the compressor at will.

A ⅜-inch oil-resistant rubber hose is connected to the compressor and extends to the supply tank situated in the rear of the vehicle. Two 15-foot ⅜-inch oil-resistant rubber hoses connect the tank to the spray boom, one being for liquid and

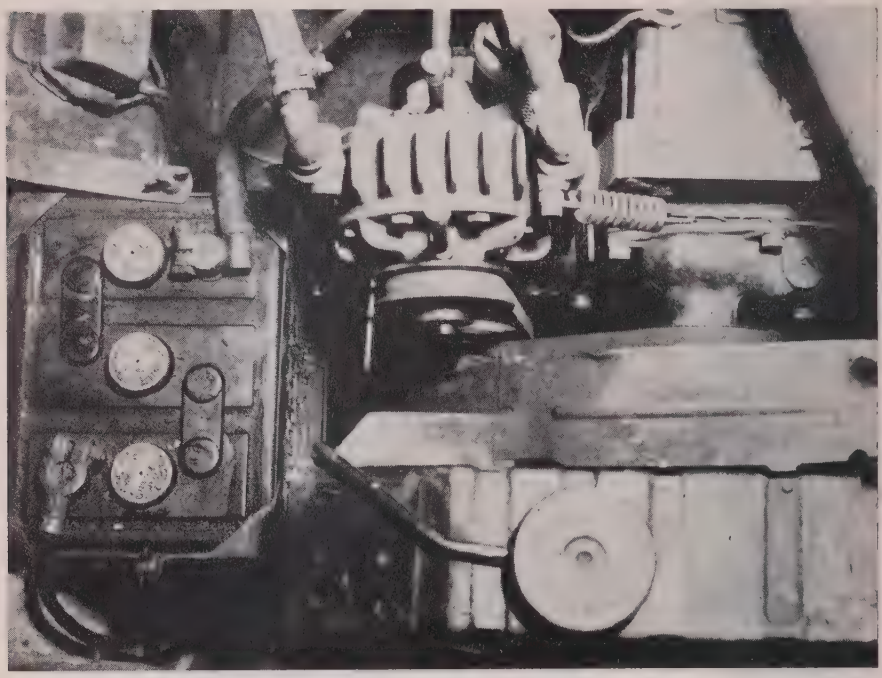

FIG. 1. Air compressor secured to cylinder head of engine.

the other for air. A valve on the liquid line enables the operator to turn the spray on and off as needed (figure 2). The air line is open at all times, allowing air to escape through the nozzles.

The unit can be mounted on a small platform equipped with wheels or skids and powered by a 2- or 2½-hp. gasoline engine or a 1-hp. electric motor (figure 3). Owing to its small size and light weight, it can either be transported in a vehicle or pulled by hand. Larger vane-type air compressors can be used to operate additional nozzles or to allow an increase in the flow rate while maintaining the same break-up of spray material.

OPERATION. The air-compressor unit will compress 8.3 cubic feet of air per minute at a pressure of 20 pounds per square inch when the vehicle is operated in low-low gear at 2 m.p.h., low gear at 4 m.p.h., or second gear at 8 m.p.h.

The liquid flow rates at various tank air pressures with the two nozzle systems are as follows:

Pounds per square inch	Gallons per hour	
	3-Nozzle system	6-Nozzle system
5	9.7	8.0
10	27.0	14.0
15	39.0	30.0

A six-outlet nozzle (set-up No. 30), is used for space sprays requiring very small droplets. When larger droplets are needed for premise treatment and outdoor areas, a three-outlet (set-up No. 29) nozzle is used, and the other three outlets on the boom are plugged. The percentages of droplets of various sizes produced by each type of nozzle are as follows:

Set-up No.	0–40μ	41–80μ	81–120μ	121–160μ	160–200μ
29	48.5	37.5	11	2.5	0.5
30	71	29			

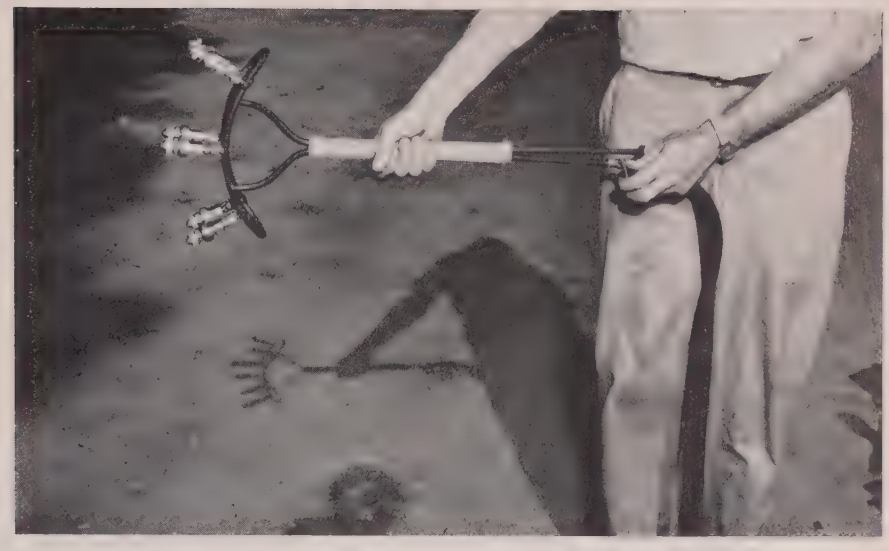

FIG. 2. Spray boom with valve for regulating liquid discharge.

LIST OF PARTS

Compressor Unit

1	1/4″ nipple
1	1/4″ tee
1	1/4″ x 3/8″ brass hose coupling
1	3/16″ x 3″ brass rod (belt guide)
1	3/8″ street elbow
1	3/8″ hose clamp
3	3/8″ elbows
1	3/8″ x 2″ nipple
2	3/8″ close nipples
1	1 1/2″ angle iron, 1/8″ thick and 9″ long
1	1/8″ x 4″ x 7 3/4″ iron plate
1	1/8″ iron plate, 5″ long, 4″ on one end, 4 1/2″ on other end
1	4″ heavy duty strap hinge
1	3/8″ (i.d.) 2-ply oil-resistant air-line hose, 10′ long
1	3 1/2″ A-section V-pulley, 9/16″ bore
1	5″ V-type A-section pulley, welded on cut-out to fit 3 1/2″ standard jeep generator pulley
1	28″ V-type A-section belt
1	6′ flexible control cable (lock type) handle
4	5/16″ x 1″ bolts and nuts
1	Tension spring, 3/16″ wire x 3″ length x 3/4″ width
1	Cable support clamp—3″ x 1 1/2″ x 1/16″

Tank

2	1/4″ (i.d.) threaded sleeve, welded in tank
1	1/8″ x 18″ standpipe
2	0–30 pound gages
1	1/4″ cross
1	1/4″ tee
3	1/4″ close nipples
3	1/4″ x 3/8″ hose couplings
3	3/8″ hose clamps
1	1/4″ regulating or bypass valve

1	5-gallon Army auxiliary gas tank
1	1/4″ liquid strainer
1	1/4″ x 1 1/2″ nipple
1	1/4″ elbow

Boom

1	1/8″ x 19″ pipe
1	1/8″ x 22″ pipe with 1/4″ x 2″ copper tubing welded in end
2	3/8″ hose clamps
1	1/8″ x 1/8″ female brass shut-off valve
1	1/8″ x 3/8″ male hose coupling
1	1/8″ x 3/8″ female hose coupling
2	3/8″ (i.d.) 2-ply oil-resistant hose, 15 feet long
1	1/4″ x 2 1/2″ copper tubing
1	1/8″ pipe coupling

Nozzle Head

2	1/4″ copper tubing, 24″ long
14	1/4″ x 1/8″ brass tubing F connections
6	Set-up No. 30 with fluid nozzle No. 40100, air nozzle No. 120–6–35–60
3	Set-up No. 29 with fluid nozzle No. 60100, air nozzle No. 140–6–52–70

The compressor unit used at the Orlando laboratory was the vane-type No. 1065–P18, manufactured by the Gast Co., Benton Harbor, Mich. Other units of similar construction may also be suitable.

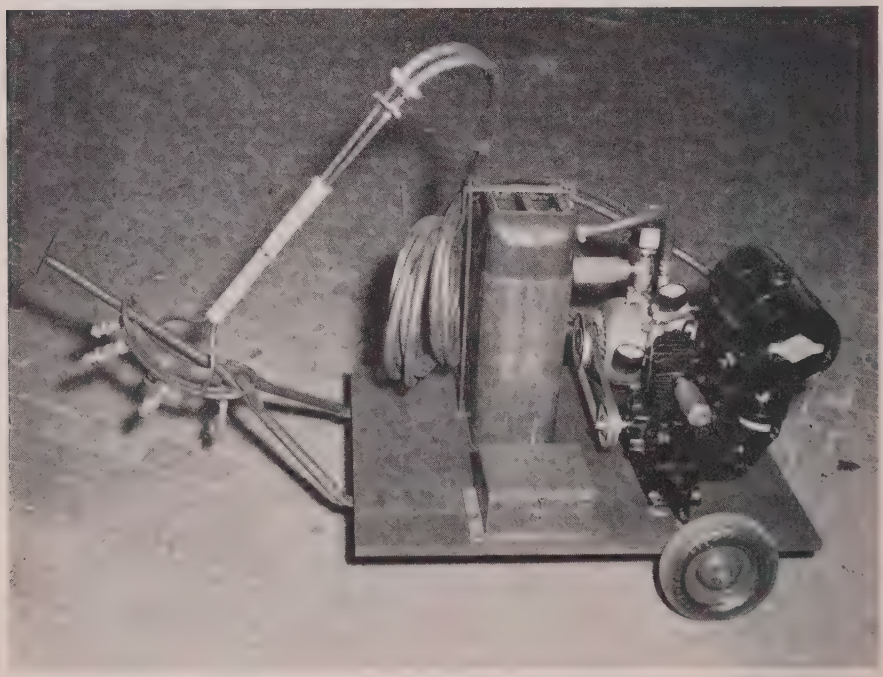

FIG. 3. Complete unit on mobile platform.

TERMINOLOGY OF CARRIERS FOR GRANULATED INSECTICIDES

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Bureau of Entomology and Plant Quarantine

Granulated insecticides are in the pioneer stage—developed far enough to offer specific challenges but not quite far enough to be bewildering. At this time it is appropriate to consider some of the terminology involved, in an attempt to keep this new field free of certain errors to which we have become accustomed. A granulated insecticide is one in which the active ingredient is incorporated with an inert carrier to give a dry granular product free of objectionable dustiness. At least 98 percent of this product should pass a U. S. No. 18 (1,000 micron) sieve and not more than 10 percent a U. S. No. 100 (149 micron) sieve. Much of the ensuing discussion is equally applicable to wettable and dusting powders.

"CARRIER" AND SIMILAR TERMS. The choice of terms to designate the inert ingredients of a formulation is often a matter of personal or group habit. Such expressions as "inert ingredients," "total inerts," and "inactive ingredients," are convenient for designating those with negligible biological activity. This language is suitable for establishing the concentration of the active ingredients, but gives no information as to origin, purpose, or function of the inert ingredients.

"Diluent" is likewise indefinite although it does imply the deliberate addition of the inactive component. The purpose of the addition is left in doubt. It may be simply convenience of handling, though there may be a hint that the object is an economic one—that is, to extend or cheapen the product. The term "filler" is in a similar category.

"Carrier" and "conditioner" have more specific meaning. They indicate a technical function of the inert material—a mechanical activity or use in spite of the chemical or biological inactivity. A carrier is a vehicle, a means of conveying the active ingredient to its place of action, and a conditioner is an agent for effecting a desirable condition, form, or physical quality in the finished product. The distinction between a carrier and a conditioner is not always sharp. The difference in function is often reflected in the percentage composition. For example, in a 50:50 blend of clay with a waxy insecticide such as DDT, the clay may be regarded as both a conditioner and a carrier, whereas in a 90 percent DDT powder with a finely divided silica as the remaining 10 percent, the function of the silica is obviously to condition the DDT, or improve its physical quality.

KINDS OF CARRIERS. In designating kinds of carriers, especially in comparative reports, it is important to distinguish between species, varieties, and grades of minerals, and, above all, to distinguish between mineralogical names and brand names.

In making comparisons it is preferable to avoid brand names. There are at least two reasons for this. First, there is the obvious consideration of business ethics. Second, there is the false sense of definiteness one may get from the use of a brand name. Usually the producers of a line of mineral carriers maintain concurrently two or more grades of the same species.

Loose tendencies are found in names and designations of minerals. Talc occurs in several forms—laminar, fibrous, granular, and modifications of these forms. Because of impurities it varies in color from white to green, and occasionally other colors are present. Its specific gravity may range from 2.7 to 3.0—the theoretical value (Gruner 1934) is 2.8. Catalysts for the decomposition of DDT are sometimes present as impurities, and sometimes not (Fleck and Haller 1945). And although

talc is a hardness-reference mineral (Mohs scale) with the nominal value of 1, its practical rating is 1–1.5 (Dana 1932). The quartz content varies from practically nothing to a conspicuous amount. Yet to many of us talc is talc. Rock species with long or cumbersome names, on the other hand, are commonly known by catchy brand names.

Among the mineral names that are inadequate characterizations in themselves are "fuller's earth" and "bentonite." These two products are prominent in connection with granulated insecticides. Some fuller's earths are essentially montmorillonite; others are mainly attapulgite. The total number of species that exist as components of fuller's earth is estimated to be in the dozens (Ries 1927). Some fuller's earths on the market have six or eight times the surface mean diameter of others. Differently processed products from the same company differ significantly in sorptive capacity and in breakdown of granules under the action of water. Bentonite is composed largely of montmorillonite, but many other components and impurities may be present, and products from different sources vary in exchangeable bases, pH value, and capacity for swelling in water.

Botanical carriers, such as rice hulls, are used occasionally in granulated insecticides, but their characterization offers no serious problem.

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ECOLOGICAL DATA ESSENTIAL TO EFFECTIVE AND ECONOMICAL CONTROL OF LITTORAL MOSQUITOES AND NUISANCE FLIES

BERTRAM I. GERRY

Massachusetts Reclamation Board

The biological gradient prevalent on the marshes scattered along the Massachusetts coastline constitutes an intriguing phenomenon. Although variations in the general appearance of individual marshes are rather obvious, the orderly distribution of aquatic organisms inhabiting these areas is somewhat obscure. Probably the most striking characteristic is the predominating floral species associated with each type of marsh. Since the distribution of both flora and fauna depend to a considerable degree upon marsh elevation, salinity, and moisture content, these dominant floral species might serve as floral labels for the various marsh types and indicate, also, the presence of the less conspicuous organisms common to their respective areas. Past experience has emphasized the value of some system, such as floral labels, which would furnish ready information relative to the ecological conditions and the probable fauna existing in areas where control treatments are contemplated. Although marsh classification, based on the presence of dominant floral species, appears fundamentally sound some adjustments should be anticipated when the suggested method is applied in a different biological or geological zone.

A brief basic conception of the geo-

logical activity which resulted in the formation of the Massachusetts marshes serves to provide a more thorough understanding of present conditions. This may be obtained from a review of that section of geological history, usually referred to as the glacial periods, when the eastern portion of the state was overlaid with glacial drift to a depth of from 100 to 300 feet. These glacial deposits consisting of sand, gravel, rubble, and clay, filled the old river valleys and extended well out into the ocean to form a continental shelf. After the glaciers receded, wave erosion produced numerous sandy peninsulas along the principal coastline. In time, the areas between these peninsulas and the mainland were built up by organic accumulations to form marshes which vary in elevation from 4 to 11 feet above mean low water. Similar accumulations produced marshes, also, in the existing estuaries and about the mouths of streams which discharged into the ocean. Since all these marshes are underlaid with a considerable depth of loose glacial drift, the water table simulates the surface of a huge water reservoir with an imperceptible surface fluctuation.

Although standardized ditches, 10 in. wide and 24 in. deep, have been installed on our coastal marshes their effectiveness varies considerably from one marsh to another. As a rule the higher marshes, i.e., those with maximum or near maximum elevation, respond to drainage sufficiently to eliminate all standing water and produce a dry firm sod. On others at lower elevations drainage is rather sluggish, and although standing water is eliminated, the actual modification in the height of the water table is so slight that the marsh surface tends to retain its original spongy condition. Those located in estuaries, or at the mouths of streams, definitely resist drainage by ditching since the stream discharge, between high tide periods, serves to hold the marsh at the saturation point—while those located on the sandy peninsulas are not subject to this drainage method because the ditching is economically impossible to maintain. Occasionally, small marshy inlets are closed off by the vagaries of loose sand accumulations or by dikes, resulting in the conversion of these areas to brackish or fresh water ponds which harbor extensive floating marshes.

The different types of marshes are described in the paragraphs which follow:

HIGH MARSH—Low water table, elevation 9–11 feet. Dominant salt marsh floral combination: primary, consisting of salt meadow grass *(Spartina patens)* and high tide shrub *(Iva oraria)*; and secondary, consisting of black grass *(Juncus gerardi)*.

Along the coastline, from Cape Cod Bay north to the New Hampshire state line, tides vary from 8 to 11 ft. and the marshes have been built up naturally to exceed 9 ft. in elevation. The dominant vegetative growth is salt meadow grass *(Spartina patens)*, although areas of maximum elevation may support patches of black grass *(Juncus gerardi)*. At the upland borders, the high tide shrub *(Iva oraria)* grows in profusion, and serves to anchor the thatch piles which function as harborages for the advanced larval stages and the pupae of the greenhead fly *(Tabanus nigrovittatus)*. In addition, the larvae of the nuisance gnat *(Dasyhilea mutabilis)* frequent the moist soil along the edges of those lateral ditches which are flushed daily by incoming tides. During the period of extreme spring tides, these larvae may be found, also, in moist areas located immediately adjacent to the lateral ditches. Whenever the temperature is favorable, and high tides or abundant rainfall produce standing water in existing depressions, the true salt marsh mosquito *(Aedes sollicitans)* may find temporary breeding sites in these high marshes.

INTERMEDIATE MARSH—Low water table, elevation to 9 feet. Dominant salt marsh floral combination: primary, consisting of salt meadow grass *(Spartina patens)*, without the high tide shrub *(Iva oraria)*; and secondary, consisting of cord grass *(Spartina alterniflora)*.

On the south shore of Cape Cod which borders Nantucket Sound, and along the shore which skirts Buzzards Bay, tides are reduced and vary from 3 to 6 ft. while the marshes show a corresponding reduction in elevation. Since the run-off is sluggish, the surface tends to retain a high percentage of moisture and large areas of cord grass are not uncommon. Occasionally, firm surfaces are encountered on the narrow marshes which show a noticeable pitch. Under these conditions, the salt meadow grass may be interspersed with patches of black grass. In instances where fresh water streams discharge on to salt marsh, the growth of three square grass *(Scirpus spp.)* may be encouraged. This condition is most prevalent on those back reaches subject to a constant flow of fresh water. Although neither the greenhead larvae nor the larvae of the nuisance gnat frequent these freshened areas, they do constitute sites for prolific breeding of the brown salt marsh mosquito *(Aedes cantator)* and the unbanded salt marsh mosquito *(Culex salinarius)*.

SATURATED MARSH—Natural water table, elevation to 9 feet. Dominant salt marsh floral combination: primary, consisting of cord grass *(Spartina alterniflora)*; and secondary, consisting of reed grass *(Spartina cynosuroides,* sometimes called *S. polystachya)*.

The saturated marshes are usually located in estuaries, or at the mouths of streams, where the constant discharge of fresh water maintains the water table at its maximum height. Although the ditching in these areas has little if any effect upon the height of the water table, it does reduce the amount of standing water and as a consequence limits breeding of both the brown salt marsh and the unbanded salt marsh mosquito. The permanent brackish pools which persist as the result of existing pot holes produce heavy broods of the biting gnat *(Culicoides obsoletus)*, and the extensive cord grass areas favor the production of a heavy population of the salt marsh tipulid *(Limonia Dicranomyia haeretica)* which often appears in quantity sufficient to constitute a real nuisance.

FLOATING MARSH—Ponded areas, elevation to 9 feet. Dominant floating marsh floral combination: primary, consisting of cattail *(Typha angustifolia)*, and secondary, consisting of water willow or swamp loosestrife *(Decodon verticillatus)*.

Because of the loose glacial drift existing along the Massachusetts coast, changes in the shore line occur frequently. In some instances inlets have been closed off by wave action or by the shifting of sand dunes, while others have been closed off deliberately by dikes. When the salinity of these isolated bodies of water falls below 100 parts per million, cattail growth *(Typha angustifolia)* may invade the water area and produce an extensive floating marsh. The suspended roots of this aquatic growth provide ideal attachments for the larvae of the irritating mosquito *(Mansonia perturbans)*, with the result that a prodigious population of this particularly vicious pest may occur. In some fresh water ponds this pest inhabits, also, the root systems of the water willow *(Decodon verticillatus)*, the button bush *(Cephalanthus occidentalis)* and various species of manna grass *(Panicularia spp.)*. Where these closed inlets receive salt water by seepage or by an indirect connection with the ocean and the salinity approaches 3,000 parts per million, only highly organized algae or pond weeds, such as *Chara* and *Potamegeton,* may persist. In these instances mosquito breeding usually becomes a minor problem, and the major nuisance is created by a mosquito-like midge *(Tendipes stigmaterus)* and a gnat-like midge, *Lauterborniella varipennis,* which appears in dense swarms from early May well into September. The latter species is particularly obnoxious, because of its ability to pass through the finest window screening in its efforts to invade the illuminated interiors of cottages.

CONCLUSION: It is evident that the control of littoral insect nuisance pests is a

Top: High marsh bearing clear stand of *Spartina patens*.
Middle: Transition from high dry marsh bearing *Spartina patens* to low moist marsh bearing *Spartina alterniflora*.
Bottom: Saturated brackish marsh at mouth of river bearing *Spartina alterniflora*.

complex problem, the solution of which requires detailed knowledge of the life history and bionomics of each individual species concerned. However, when adequate information is available, one may then concentrate attacks at those vulnerable points which provide the most effective and most economical control. To illustrate: (1) in control of the greenhead fly, only that small portion of marsh marked by high tide shrubs and the thatch piles from which the majority of adults emerge, need be treated; (2) in the control of the biting gnat, treatment is confined to that section of saturated marsh containing pot holes, and the vegetative borders of the slightly brackish ponds located adjacent to the seashore; and (3) in *Mansonia* control, treatment is limited to those hard bottomed ponds or lakes containing floating marsh, since the irritating mosquito cannot survive on cattails or water willow when their roots are imbedded in a hard bottom.

AN *ANOPHELES QUADRIMACULATUS* LARVA WITH THREE INNER CLYPEAL HAIRS [1]

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In checking over some fourth instar larvae of *Anopheles quadrimaculatus* Say, which were collected in 1944 at the Naval Advance Base Depot, Davisville, Rhode Island, an abnormal specimen was found having three inner clypeal hairs instead of two (Fig. 1).

Under the compound microscope, it was seen that the two outer hairs are the normal ones, whereas the middle one is in excess. The outer ones are wider apart than is usual for the species. The tubercle of the middle hair lies ventrad to the other two tubercles at a distance equal to one-half the diameter of a tubercle. All the other hairs and characteristics are normal.

This larva was collected in a large, clear pond having grassy margins, together with about fifty other larvae of the same species, but no other abnormal specimen was found.

The writer has seen mosquito larvae with abnormal gills, siphons, siphonal hairs, and anal segments, but this was the first one seen having a third inner clypeal hair.

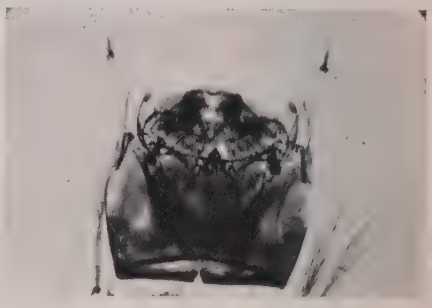

FIG. 1. Fourth-instar larva of *Anopheles quadrimaculatus* Say having three inner clypeal hairs.

[1] The material presented here in no way constitutes an indorsement by the Department of Defense.

STUDIES ON THE ARTIFICIAL INSEMINATION OF THE MOSQUITO *AEDES AEGYPTI* (LINNAEUS)[1]

RICHARD O. HAYES[2]

A successful method by which female mosquitoes could be artificially inseminated could conceivably provide the means for the establishment of laboratory colonies which do not normally mate under laboratory conditions. To date, the inability to colonize many species of mosquitoes has been the limiting factor in the study of various aspects of their biology, of their importance and potentiality as disease vectors, and of their hereditary characteristics.

This study was made to determine the feasibility of artificially inseminating *Aedes aegypti* (Linnaeus) mosquitoes. The ramifications of the problem included the study of their reproductive organs, the characteristics of the spermatozoa, the design and trial of insemination equipment, and the development of insemination techniques.

The establishment and maintenance of a mosquito colony was a primary requisite for the study. Dormant viable mosquito eggs adhering to paper toweling were placed in a pan of distilled water. Upon hatching the larvae were fed a mixture of finely ground dog food and brewer's yeast. To prevent the accumulation of larval food only small quantities were given at a daily feeding. Excess food, which eventually decomposed, was found to be detrimental to larval growth and development. The larvae were allowed to pupate and emerge in a rearing cage which was approximately 22 x 22 x 22 inches large. The adults were provided honey as a source of food. A rabbit was placed in the cage approximately every third day as the source of the blood meal necessary for mosquito egg development. The female mosquitoes oviposited upon moist paper toweling placed within the cage for that purpose. The toweling with the adhering eggs was periodically removed and stored in a humidor for future use.

The majority of the pupae were allowed to emerge in the rearing cage. However, a small percent of the female pupae were transferred to small plastic boxes, 1 x 1 x 1 inch large, and placed in holding cages. The holding cages were assembled by merely placing a lamp chimney within the cover or bottom of a Petri dish. A piece of bobbinet cloth was used to cover the other end of the chimney. The female pupae were easily separated from the male pupae, for they are distinctly larger than the males. In this manner it was possible to establish and maintain a suitable virgin female population for the study.

INTERNAL MORPHOLOGY OF REPRODUCTIVE ORGANS

The nature of the study required a thorough working knowledge of the morphology of the mosquito's reproductive organs. The description of these organs, which follows, is concerned principally with the internal structure.

It should be noted that the differences found in the adult external terminalia, especially that of the male, have been widely used in classification of mosquitoes. Discussions of the morphology of the external male and female genitalia can be found in the literature.

MALE. Figure 1 is a ventral view showing the internal and external male reproductive organs. It will be seen that the male generative organs consist of a pair of testes which are dorsally located in the 8th abdominal segment, from which the sperm is carried by the lateral sperm

[1] This project was conducted in partial fulfillment of the requirement for the degree of Doctor of Philosophy at Cornell University, Ithaca, New York.

[2] The author wishes to acknowledge the suggestions and constructive criticisms offered by Professor Bernard V. Travis, Department of Entomology, Cornell University.

ducts to the common sperm duct. Ducts from the accessory glands join the common sperm duct shortly before it terminates in the phallus. The phallus is surrounded by an elaborate arrangement of claspers and various chitinous structures which are collectively termed the genitalia.

FEMALE. The internal female reproductive organs are shown in a dorsal view in figure 2. The two ovaries, which lie dorsolaterally, are found in the 6th and 7th abdominal segments. From each ovary arises a short lateral oviduct. The lateral oviducts unite to form the common oviduct which extends posteriorly to its external opening, the bursal pouch, in the

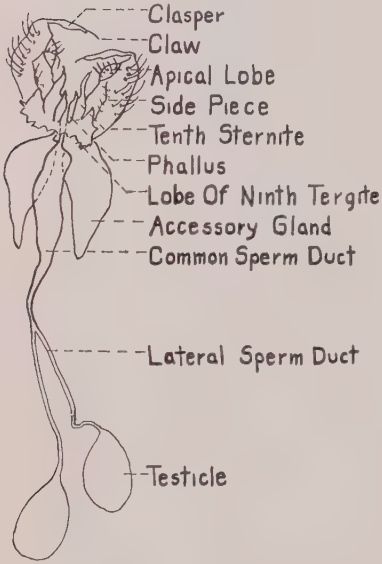

Figure 1

240μ

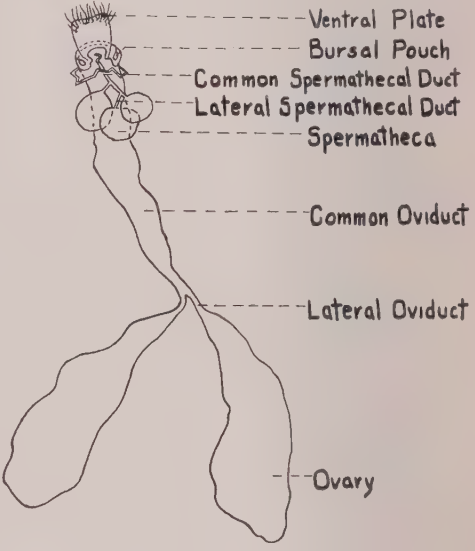

Figure 2

320μ

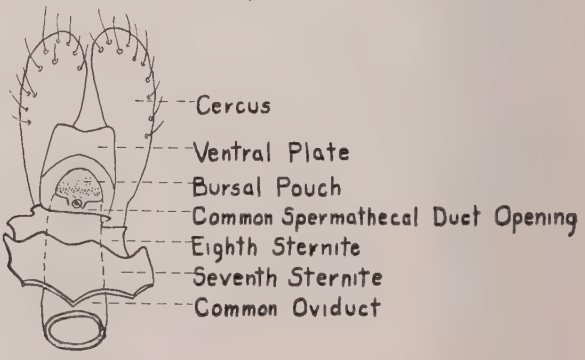

Figure 3

160μ

8th segment. The three spermathecae which are readily observed as perforated chitinous sub-spherical bodies are attached by long narrow ducts which open jointly into the bursal pouch.

Figure 3 shows the opening of the common oviduct and the spermathecal duct opening from an external ventral view. The bursal pouch is a purse-like folding membrane normally drawn within a protective sheath formed by the 8th abdominal segment. The spermathecal duct opening, which is only 8 microns in diameter, is surrounded by a rigid sclerotic disc located medianly on the anterior dorsal surface of the bursal pouch. The ventral plate and the adjacent bursal pouch were pulled out for the purpose of the illustration.

Evaluation of Spermatozoa

An evaluation of the sperm characteristics involved consideration of their appearance, abundance, and physiological requirements.

Morphology. The spermatozoa consist of a long filamentous tail attached to an equally slender needle-like body. The sperm cells were found to average 0.7 microns in diameter and 132 microns in length. Of their over-all length, the body piece occupied 22 microns. No distinct division of the body piece into a head and a middle piece was observed in living or stained sperm when using 97X oil immersion lenses and 15X eyepieces on either a standard compound microscope or a phase microscope.

The filamentous tail of each sperm cell contained four or five large undulations which occupied its entire length. Small secondary waves within these undulations gave the tail a sinuous appearance.

Spermatozoa were stained only in their body region by basic stains. Giemsa's spirochete stain and Heidenhain's iron haematoxylin stain were the dyes used. The stain reaction indicated the presence of chromatin material in this region.

The definite body and tail regions could also be readily observed as the unstained living spermatozoa moved actively about in their characteristic rotary motion.

Enumeration. The number of sperm cells per cubic centimeter was determined with the aid of a double Improved Neubauer hemacytometer. Knowing the original fluid volume, the number of sperm available was then readily calculated.

A series of five counts showed the average number of sperm available to be 15,000. Since it was impossible to be sure that all the sperm had been removed from the reproductive organs, this number was not considered to represent the total number of spermatozoa. It was, however, believed to be an estimate of the average number of sperm present upon dissection and available for transfer.

Physiology. Some of the more important physical factors which are known to effect physiological activities were investigated. Temperatures above 40 degrees Centigrade were found to be lethal to the spermatozoa. The minimum lethal temperature was not determined, but reduced sperm activity was noted at 20 degrees Centigrade. The use of a heat absorbing thick frosted-glass filter on the microscope lamp was found to be essential for the reduction of heat produced by the lamp. The type of cool light described by Patton (1943) was also satisfactorily used to prevent heat fixing the sperm.

Sperm in uncovered drops generally remained active 15 minutes. Sperm in covered drops usually remained active 30 minutes. This was thought to reflect some deleterious effect due to oxidation. However, similar results were observed when covered and uncovered drops containing sperm were placed in an atmosphere of carbon dioxide.

A modified Belar (1929) saline solution having a pH of 6.9 was found to be the most satisfactory perfusion medium for sperm transfer. The determination of the osmotic pressure, the proper salt balance, and the hydrogen ion concentration was necessarily based upon that of the body fluid, and a paper concerning this problem is in preparation for publication at a later date.

INSEMINATION STUDIES

Attempts were made to devise equipment which could be used to satisfactorily carry and deposit viable sperm in the female mosquito. A uniform system was established for the handling of the mosquitoes preparatory to and following attempted artificial inseminations, and several seemingly logical insemination procedures were investigated.

EQUIPMENT. Five syringes were investigated to determine a means of transferring the sperm to the female.

Syringes utilizing a machinist's type of micrometer caliper, a tuberculin syringe, and a variable transformer as their source of force to produce motion were investigated. However, a syringe assembled by merely fitting a glass micropipette within a short, approximately ten inches long, piece of transparent Polyethylene medical tubing was found to be the easiest to operate and the most satisfactory of all the syringes investigated. Its low cost of production, simplicity of construction, and lack of movable parts and connections requiring gaskets were also definitely advantageous.

The tubing had an 0.07 inch inside diameter and an outside diameter of 0.11 inch. De Khotinsky cement, medium grade, was used to secure the conduit to the micropipette. The micropipette tip was drawn from 0.07 inch soft glass tubing. The technique used was essentially that outlined by Barber (1914). A common laboratory microburner and one made from the tip of a number 27 Becton, Dickinson Yale syringe needle were used in drawing the glass. A finished micropipette tip had an outside diameter no greater than 50 microns and a bore diameter of less than 12 microns.

In operation the free end of the tubing was held in the operator's mouth, and movement in the system resulted from his application of positive or negative air pressure. The force providing the movement within the system could therefore be applied without the use of the operator's hands. Thus, the left hand was used for focusing the microscope or moving the object being worked upon, and the right hand could be used to direct the micropipette. It was found that with practice it was possible to discontinue the use of a micromanipulator and to hold and direct the micropipette with the right hand. The resulting spontaneous freedom of motion in all planes was an advantage of paramount importance.

A balsa wood holding block and staples fashioned from minuten insect pins were designed and found to be satisfactory for holding the females securely, without injury, during the insemination operation. Merely securing the mosquito to prevent flight was found to be unsatisfactory, since the abdominal movements of the female made complete immobilization necessary. Even though it was possible to hold the abdomen firmly enough to prevent lateral or verticle motion, it was not possible to prevent an avoiding reaction of the terminalia. This avoiding reaction consisted of a retraction of the genital region within the eighth abdominal segment to an even greater extent than to which it was normally retracted. This made the insertion of the micropipette tip into the bursal region exceedingly difficult. The retraction method of transferring sperm into the bursa of the female, to be described later, overcame the avoiding reaction difficulty to some extent.

HANDLING PROCEDURE. Untreated males which were at least 24 hours old were taken from the holding cage by means of an aspirator and were anesthetized with a mixture of carbon dioxide and air. They were then placed in a carbon dioxide atmosphere on a filter paper within a Buchner funnel. The apparatus utilized for maintaining the state of continuous anesthetization was similar to that described by Williams (1946). Each mosquito's wings and legs were removed immediately prior to its being placed upon a microscope slide and dissected.

The female mosquitoes were anesthetized in the same manner as the males. The female was then placed on her back in such a position on the pinning block that the tip of her abdomen would reach

the edge of the pinning surface. The minuten staples were then placed in position with the aid of fine-pointed jeweler's forceps. Usually three staples were found to be sufficient for securing the mosquito. The staples were placed about the body at the cervical, thoracic, and posterior abdominal regions.

Following the attempt at artificial insemination, the female was placed in a lamp chimney holding cage. Twelve hours later the female was allowed to obtain a blood meal. The twelve hour holding period served to insure feeding only those females not injured by the operation, the injured usually having died during that period. A strip of moist toweling was then made available, within the holding cage, as an oviposition site.

INSEMINATION PROCEDURE. The instrumental insemination procedure involved obtaining viable sperm from the male and transferring it to the bursal region of the female.

Several techniques were investigated in attempts to obtain the sperm. Only males at least 24 hours old were used. These were seldom devoid of sperm, but it was noticed that males dissected soon after emergence did not contain a supply of active spermatozoa. This situation may be be related to the phenomenon reported by Roth (1948), who, while working with *A. aegypti,* observed that the male genitalia must undergo a nearly 180 degree rotation before copulation can be successfully completed. He also showed that it seldom required more than 25 hours for the rotation to be completed.

The dissection of male mosquitoes was carried out in a drop of physiological salt solution. Minuten insect pins mounted in wooden applicator sticks were used to sever the abdomen between the 7th and 8th abdominal segments and to remove the posterior sternites and tergites. The male reproductive organs were then cut at the point where the common sperm duct enters the phallus and were transferred to a smaller drop of saline solution. If debris had not accumulated in the dissecting medium during the course of the operation, the testes, the sperm duct, and the accessory glands were not transferred. A dissecting microscope having wide field oculars and a magnification of 30 diameters facilitated the operation.

To release the spermatozoa, the common sperm duct, lying between the two accessory glands, was cut at the point where it entered the phallus. The sperm then flowed from the common sperm duct and commenced to actively disperse throughout the drop of saline.

Attempts to squeeze sperm from intact males, as can be done in the case of drone bees, have failed. The diminutive size of the insect made it seemingly impossible to evert the phallus and force sperm from the reproductive organs by the application of external pressure.

Although Rees and Onishi (1951) were able to cause the sclerotized plates of the phallus, in *Culiseta inornata* (Williston), to be extended by stimulation shortly following copulation, no noticeable response was observed to the rubbing of the *A. aegypti* terminalia. Stimulation in this manner failed to lead to the production of an available sperm supply.

Attempts were made to bring about an ejaculation by the mosquitoes as the sympathetic resultant of a shock reaction. Ejaculation failed to be induced, however, by the methods of shock utilized.

The transfer of viable sperm into the bursal region of the virgin female mosquitoes was accomplished by several methods. An injection method was utilized by directing the micropipette tip into the bursa of the female. The sperm were then discharged directly from the syringe into the bursal pouch. In some cases, only a small quantity of the sperm suspension was introduced, and the micropipette tip was immediately withdrawn. At other times, a relatively large amount of the spermatozoal fluid was injected to form a drop which adhered to the genital region. Still other trials were conducted in which prolonged or repeated transfers were made, both with the sparse and the voluminous types of injection.

Due to the minute size of the spermath-

ecal duct opening, 8.0 microns in diameter, and its inflexible characteristic, attempts to inject the spermatozoa directly into the spermathecal ducts were unsuccessful.

In several instances all glass contacting the sperm suspension was treated with an anti-wetting agent to prevent physical damage to the sperm due to contact with the glass.

It should be stated that the technique for exposing the bursal pouch, to be next described, was incorporated in many of the injection method transfers.

The retraction method consisted of grasping the ventral plate of the female with fine-pointed jeweler's forceps and gently pulling with the right hand so as to expose the bursal pouch. The excised testes and common sperm duct of the male were then placed directly upon the extended purse-like bursal pouch and ruptured to liberate the sperm. The ventral plate was then released, and as the ventral plate and the adjacent bursal pouch retracted to their normal position within the 8th abdominal segment, the released sperm were carried along. The introduction of spermathecae containing viable sperm removed from naturally mated females was also accomplished in this manner. The spermathecae were crushed to liberate the sperm immediately prior to releasing the ventral plate.

The debris was removed 24 hours after the operation to prevent its interference with subsequent oviposition, and to eliminate it as a source of bacterial infection.

RESULTS

To date, the artificial insemination of 105 virgin *A. aegypti* females has been attempted. Six of the mosquitoes did not survive the 24 hours holding period; the rest, however, lived at least one day and were given an opportunity to take a blood meal. Fifty-seven of the treated females became engorged, and thirteen of these individuals were induced to feed upon more than one occasion. Two blood meals were the maximum number to be taken by any of the mosquitoes. Only two of the engorged females failed to survive the minimum four days required of oviposition following the blood meal. One female survived 57 days following the attempted instrumental insemination and the blood meal.

A total of 542 eggs were laid by 22 of the test females. As a result of repeated blood meals, five of the mosquitoes laid eggs upon two separate occasions. The maximum number of eggs laid by a female during a single oviposition period was 75 eggs. The largest number of eggs obtained from a single mosquito was 85; this was, however, the sum of the eggs produced upon two separate oviposition occasions. The minimum number of eggs laid by an individual was one. Four mosquitoes were observed to have laid a single ovum, whereas a single egg was laid by another female following a second blood meal and an earlier egg batch. One egg was laid by a female which had not partaken of a blood meal, and one egg was produced by one of twenty blood-fed virgin female mosquitoes, which were untreated.

Approximately ten percent of the test mosquitoes were sacrificed to permit an inspection of their spermathecae. Unfed and fed females which had survived the attempted instrumental insemination but which had not laid eggs, and mosquitoes which had fed and oviposited were examined. In no case was a spermatheca observed which contained sperm.

None of the eggs laid by the treated females hatched to produce larvae. Many of the submerged eggs collapsed and were readily seen to be nonviable. Upon dissection, none of the remaining eggs were found to be viable.

All females which had mated naturally, and which were subjected to the techniques of artificial insemination employed, produced normal numbers of viable eggs.

DISCUSSION AND CONCLUSION

The studies upon the instrumental insemination of mosquitoes were necessarily attempts to duplicate the phenomenon effected by a natural mating.

Marshall (1938) reported fertilization in mosquitoes to take place at the time of oviposition. At that time, the spermatozoa travel from the spermathecae and enter the egg through the micropyle as it passes the opening of the spermathecal ducts. Thus the problem was basically one of transferring viable sperm, which would fertilize eggs during oviposition, to the female.

Giles (1902) believed the Culicid spermatic element of the male to be "transferred *en masse* from the receptacles of the male to those of the female." In this study, the transfer of active sperm into the bursa of the female was successfully accomplished, for it was possible to recover the active sperm immediately following a transfer. Clean micropipettes were used in making all such recoveries.

Attempts to deposit sperm in the spermathecal ducts were unsuccessful, due to the minute size of the duct's external orifice. Watson (1927), and workers to date, met with the same difficulty in the queen bee. He, however, observed that the bee sperm was deposited in the oviduct, and that the sperm migrated by their own activity to the spermatheca of the female. At the present time, there is no evidence to indicate that such is not the case in mosquitoes.

Had the attempts at artificial insemination by transferring sperm-filled spermathecae of naturally mated females been successful, as was reported by Gottschewski (1937) using *Drosophila melanogaster* Meigen, it would not have provided a means of maintaining colonies of mosquitoes which do not normally mate under laboratory conditions, since it would require a source of naturally mated female mosquitoes.

The males and females utilized ranged from one to six days old; adult *A. aegypti* of this age group were shown by Roth (1948) to be capable of successful matings.

Future studies upon the artificial insemination of the mosquito will be conducted to seek an explanation for the failure of the sperm to survive the transfer and migrate into the spermathecae. It is hoped that sperm transfer will be facilitated in these studies by the development of a holding device which readily exposes the bursal area and at the same time prevents the avoiding reaction of the female.

The diminutive size of the mosquito imposed strict limits upon the specifications of the equipment design and upon the techniques of sperm transfer. Due to these limitations, it was not possible to obtain and transfer undiluted sperm by a pipette method, as is done for the artificial insemination of other insects.

The production of viable eggs by treated naturally mated females and of sterile eggs by females treated either before or following a blood meal indicated the technique had no deleterious effects upon oviposition. It was, therefore, concluded that the inability of the sperm to survive the transfer and to fertilize the eggs during oviposition resulted in the production of sterile eggs.

Summary

Attempts to artificially inseminate the mosquito *Aedes aegypti* (Linnaeus) were made. The important features of the mosquito culture technique, the anatomy of the sex organs, the evaluation of the spermatozoa, and the insemination studies were described. Twenty of 105 treated females laid a total of 542 eggs, but the inability of the sperm to survive the transfer and fertilize the eggs during oviposition resulted in the production of sterile eggs.

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THE EFFECT OF CONTAMINATION UPON MOSQUITO LARVAE IN RAIN-WATER BARRELS

CHARLES O. MASTERS

For several years, six rain-water barrels located in a rather poorly-lighted place adjacent to a dense beech-maple forest in Cuyahoga County, Ohio served as favorite collecting spots for various species of mosquito larvae.

During the months of May and June, 1952, these barrels teemed with larvae of *Aedes triseriatus, Culex pipiens,* and *C. restuans,* with *A. triseriatus* dominating. On July first, the author accidently upset the contents of a kitchen garbage container in one of the barrels. It was decided to continue making regular collections from all six barrels and note whether or not there would be any differences in the mosquito populations of the barrels. Following are the results of these observations.

July 1, 1952—All six barrels contained mosquito larvae in approximately these proportions: *A. triseriatus,* 6; *C. pipiens,* 2; *C. restuans,* 1. Added garbage to barrel number six only.

July 15, 1952—Barrels one to five still maintaining the proportion of larvae as described previously. Barrel number six very foul and odoriferous, no larvae present.

July 30, 1952—No apparent changes in the mosquito population of barrels one to five. Number six teeming with *C. pipiens* only.

September 3, 1952—Barrels one to five contained only *A. triseriatus.* Barrel number six contained only *C. restuans.*

September 14, 1952—Barrels one to five contained *A. triseriatus* and *C. pipiens* in the proportion of six to one. *C. restuans* had disappeared entirely.

Barrel number six teemed with *C. restuans* only.

September 20, 1952—Barrels one to five contained *A. triseriatus* and *C. pipiens* in the proportion of one to one.

Barrel number six teemed with *C. restuans.*

October 1, 1952—Barrels one to five contained *A. triseriatus* and *C. pipiens* in the proportion of one to one.

Barrel number six contained *C. restuans* only.

From these collections made during the summer of 1952, it looked as if the addition of the garbage to barrel number six immediately eliminated all larvae; then as it was diluted by rain *C. pipiens* first appeared only to be completely replaced by *C. restuans* which remained for the rest of the season. *A. triseriatus* never did reappear in barrel six, possibly because of the contaminating material present but it was speculative as to why *C. restuans* seemed to "prefer" the contaminated barrel only in which to breed after the first of July.

A PRELIMINARY REPORT ON THE LABORATORY COLONIZATION OF THE MOSQUITO, *CULEX TARSALIS* COQUILLETT [1]

JAMES M. BRENNAN [2] AND ROBERT F. HARWOOD [3]

INTRODUCTION. In the epidemiology of western equine encephalitis, *Culex tarsalis* appears to be the most important mosquito species concerned. It is the only mosquito from which the virus has been repeatedly isolated during epidemic and nonepidemic years. In some endemic areas this species is probably an important vector in the transmission of the virus to man. At present it seems that the only promising approach to the study of the ecology of the virus is through the bionomics of *C. tarsalis*. Isolations of the viruses of both St. Louis and California encephalitis from this same mosquito suggest its further medical importance. The need, then, of a laboratory colony of *C. tarsalis* is obvious.

Dr. Bernard Brookman working at Bakersfield, California, in 1951, reported (personal communication) the continuous rearing of the species outdoors from May to October when the females, apparently entering a diapause, refused further blood meals and the declining colony was permitted to expire. His attempts to establish a colony indoors were unsuccesful. Also in 1951, the senior author experienced some measure of success in rearing the species in the laboratory through three generations, but efforts to establish a colony were unsuccessful. It thus became apparent that, although *C. tarsalis* is a common and widely distributed mosquito in North America with diversified larval habitats ranging from the thermal springs to liquid manure, the usual rearing techniques were unsuitable for successful laboratory colonization of the species.

A method developed in August 1952 and currently in use at the Rocky Mountain Laboratory, while still somewhat cumbersome, has resulted in the successful colonization of *C. tarsalis*. The colony, now in its tenth generation (estimated, since no effort was made to record generations beyond F_4), is flourishing. Adult and larval mortality has been minimal. The adults are large and vigorous. There has been no suggestion of a diapause.

The growth of the principal colony is perhaps best reflected in egg raft production. During the period of 15 October to 31 December, 107 rafts (1.4 per day) were deposited; 78 (73%) contained viable eggs. During the period of 1 January to 10 March, 787 rafts (11.4 per day) were deposited; 600 (76%) contained viable eggs.

MATERIALS AND METHODS. In earlier experiments, inducing mating in captivity had been the chief obstacle in the continuous rearing of *C. tarsalis* (a eurygamous species). This prompted more critical observations of the correlation between adult sexual behavior and environmental conditions in nature. From these observations it seemed expedient to initiate a rearing technique based on a process of conditioning adults by simulating as accurately as possible in the laboratory the presumed factors which stimulate mating. The conditioning routine was derived from a composite day of a number of summer days in Hamilton, Montana, when prevailing conditions were favorable to swarming, emphasis being placed on the critical periods of dawn and twilight, i.e., the periods of peak activity for *C. tarsalis*.

The technique described below is flexible and should lend itself readily to modification to meet existing needs. Although

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certain steps may not be essential, and others can be eliminated, when feasible, or as evidence of adaptability is obtained from succeeding generations, it appears that a conditioning process, at least for the earlier generations, is fundamental to the success of colonizing *C. tarsalis*.

The Rocky Mountain Laboratory strain is a mixture started with gravid females from Bismarck, North Dakota, and eggs, larvae, and pupae from Hamilton, Montana, all collected in midsummer of 1952.

Adults of the first laboratory generation were subjected to an artificial day by caging them in a windowless room of the insectary where light, temperature, and humidity are controlled, either automatically or manually, as desired.

Cages. The main colony cage (Fig. 1) of metal screen and wood frame is a large, portable, walk-in model without a floor, and is approximately 7 feet high, 6 feet

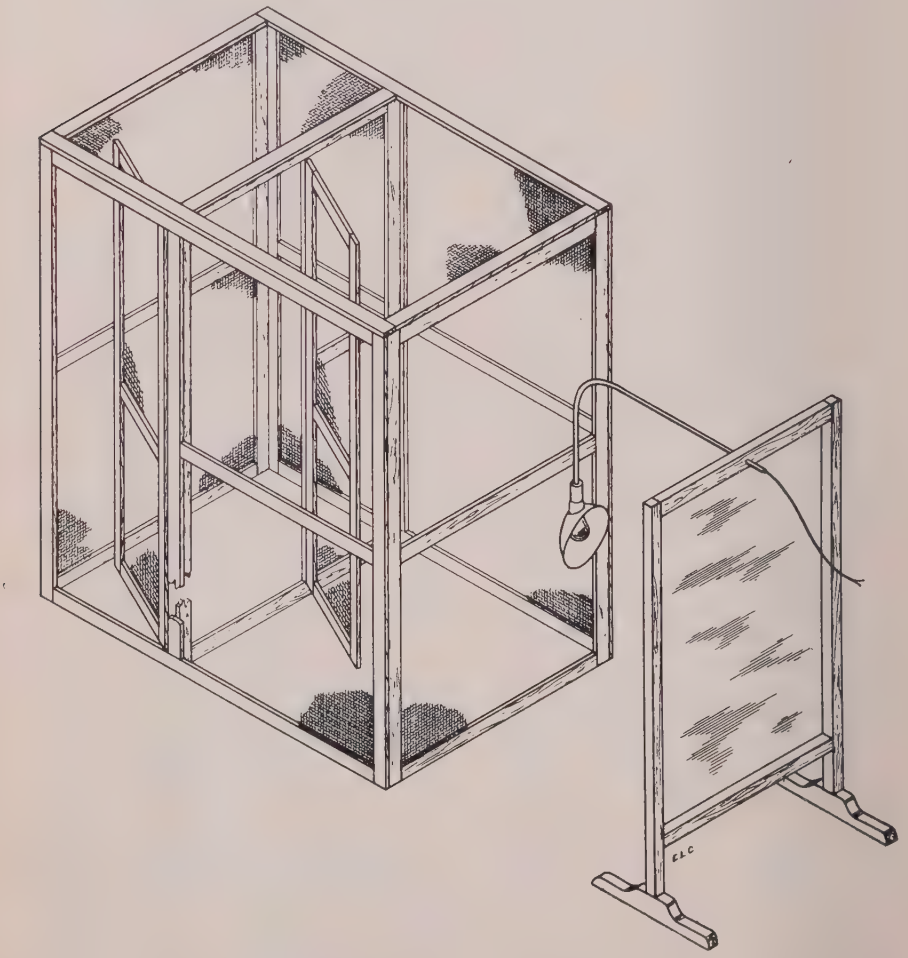

FIG. 1. Isometric projection of main colony cage, rheostat-controlled lamp and screen as arranged for the conditioning and continuous rearing of *Culex tarsalis*.

long, and 4 feet wide. The cage is divided into two compartments. An outer screen door opens into an entrance lock, or trap, (2 x 4 feet) from which an inner screen door opens into the mosquito chamber (4 x 4 feet). The doors are so placed that the inner can not be opened until the outer is closed. A small sleeve in the wall between the mosquito chamber and the trap is convenient.

Small cages (16 x 16 x 24 inches) of the conventional sleeve-equipped type are also used, but to date, not with the degree of success achieved in the walk-in cage since a large space is more conducive to swarming.

ADULTS: CARE AND CONDITIONING. The conditioning routine is begun immediately with the F_1 adults in the walk-in cage. The daily cycle is divided into four parts: A day period of about 16 hours, a twilight period of about 1 hour, a night period of about 6 hours, and a dawn period of about 1 hour.

During the day period the temperature may range from 75° to 79° F with a relative humidity of about 40%. The source of light is entirely artificial and is produced by overhead fluorescent tubes of the daylight type and a rheostat-controlled 300-watt lamp located just outside the mosquito compartment into which it is reflected by a white screen (Fig 1). Under conditions of full daylight, with all ceiling lights operating and the rheostat set at 110 volts, the intensity is such that a reading, taken in the center of the cage, on a Weston Master II Exposure Meter directed toward the reflecting screen is 13.

Throughout this lengthy day period the mosquitoes are resting in the darker portions of the cage, for the most part concentrated on the higher parts of the framework. They exhibit little activity except when disturbed, or when feeding on a 10% sugar solution which is constantly available in soaked cotton pads distributed on top of the cage.

A short period of twilight provides a gradual transition from day to night. This critical period is begun by setting thermostat and humidistat at 60° and 70% respectively and switching off ceiling lights. In the center of the cage the exposure meter reading is 6.5. For the next half hour or longer the light intensity from the rheostat-controlled lamp is slowly decreased by reducing the voltage, in about 10 steps, from 110 to 0. This operation is performed manually since it is desirable to make frequent observations of mosquito responses.

Mosquito activity begins early in the twilight period and is continuous throughout. Swarming is performed by the males with an occasional female participating. This behavior in the laboratory parallels closely the phenomenon as observed in the field. Swarming is accompanied by few to numerous matings on the wing as females fly through the swarm, and usually reaches a peak when voltage settings on the rheostat are between 45 and 30. At this interval the readings on the exposure meter in the center of the cage are from 0.3 to 0.1 (estimated). When it is desired to prolong the swarm period, the stepping-down procedure with the rheostat is discontinued for nearly an hour, then continued to darkness.

Two or three times weekly, during the night period, blood meals are provided for the females by suspending a half-grown chicken in a restraining cage of chicken wire from the top of the mosquito cage. Guinea pig blood is acceptable, but chicken blood appears to be preferred and definitely contributes to the production of larger egg rafts.

The dawn period is merely a reversal of the twilight period. The thermostat and humidistat are set at 75° and 40% respectively. The intensity of the rheostat-controlled lamp is gradually increased from 0 to 110 volts and the overhead lights are switched on. Swarming and mating occur at this time, but not to the extent observed at twilight.

This conditioning process was continued as a daily routine for about 6 generations when it was demonstrated that certain steps could be eliminated without jeopardizing the colony. With the next generation temperature and humidity were main-

tained at 70° and 70% respectively throughout the 24-hour cycle, and with the succeeding generation the dawn period was eliminated entirely. The decreasing light intensity during the twilight period seemed essential and was continued. Occasionally the colony was purposely neglected and it remained over week ends under constant daylight conditions with no adverse effects.

EGGS. Oviposition takes place, either during darkness or light, directly in the larval pans which, for convenience and to save space, are kept in a cross-stacked pile on the floor in the walk-in cage. The egg rafts are collected daily in beakers of distilled water.[4] Upon hatching, which takes place 2 to 3 days after oviposition, the young larvae are poured into freshly prepared pans.

From Table 1, based on one day's egg production, it will be noted that the average number of eggs per raft was 230 with a viability of over 83%, and that on this particular day 100% hatching occurred in 9 of 21 egg rafts produced.

TABLE 1. Egg production and viability (23 January 1953)

Raft No.	No. Eggs	No. Eggs Hatched
1	272	106
2	302	302
3	138	138
4	221	221
5	271	271
6	117	112
7	333	333
8	291	212
9	295	295
10	239	135
11	294	294
12	187	129
13	272	266
14	143	121
15	139	139
16	162	106
17	193	180
18	208	162
19	227	224
20	279	279
21	265	12
Total	4848	4037

Average eggs per raft: 230. Percent viability: 83.3.

LARVAE. In preparing a fresh larval culture, a white enameled pan, 2½ x 12 x 18 inches in size, is filled with distilled water to a depth of about ½ inch. About 0.5 gm. of a crushed pellet[5] of high protein content (32%) and about 1.0 gm. of a mixture of equal parts brewer's yeast and dried milk are diffused through the water. A pan thus prepared readily accommodates 300 to 500 larvae without crowding. A whole high protein pellet is added every third day until pupation.

The larvae are for the most part surface feeders and their activities appear sufficient to keep the water fairly clean. When an occasional surface film forms, it is easily removed by sweeping the water surface with a sheet of paper. Dead larvae are not removed. The duration of the larval stages varies from 8 to 13 days, and averages 10 days.

PUPAE. Pupae may be handled as desired. Pupation, which requires about 3 days, occurs in the larval pans and the adults emerge directly into the cage.

From the above it will be seen that in the continuous maintenance of *C. tarsalis*, the entire life cycle and the concomitant overlapping of generations occur within the main colony cage. Under the conditions described, the time required to complete the life cycle is approximately 25 days.

As suggested earlier, continuous rearing in smaller cages is not so productive as in the walk-in cage. When about 350 F_5 and F_6 pupae from the main colony were transferred to small cages in the conditioning room, the emerging females and those of two succeeding generations deposited 375 egg rafts at the rate of 4.6 per day during the period of 13 January to 3 April. Of these, only 167 (44%) contained viable eggs. However, except for this lower via-

[4] Distilled water is used throughout our rearing technique. The tap water available is undesirable because of the formation of a pellicle after standing.

[5] *Hi-Protein Supplement*, Misco Mills, Missoula, Montana.

bility index, no other significant change has been observed. The adults continue to be robust, feed readily, and swarm. Larval and adult mortality appears to be no greater than normally expected.

The erratic results from attempted rearings (again starting with F_5 and F_6 pupae from the stock colony) in small cages in a window-equipped room at a constant temperature and humidity of about 70° and 70% do not warrant further reporting at this time.

Up to the present time no serious effort has been made to determine longevity of captive adults. However, some males have been observed to live 2½ months and some females more than 4 months.

SUMMARY

A method is described for the continuous rearing of *Culex tarsalis* Coq. in the laboratory.

The adults are eurygamous; therefore it appears that successful colonization is contingent upon their induced adaptation to captivity by a conditioning process which has as its basis a day simulated from nature when conditions are favorable to sexual responses. A relatively large space and a variable light intensity are the principal factors required to stimulate swarming and mating.

A satisfactory diet for adults is chicken blood and sucrose; and for larvae a proprietary pellet of high protein content supplemented with brewer's yeast and dried milk is suitable.

Approximately 75% of all egg rafts from the principal colony contain viable eggs. In one day's production of 21 rafts, the average number of eggs per raft was 230 and the viability was somewhat greater than 83%.

ACKNOWLEDGMENT. The helpful suggestions and assistance of Alexander A. Hubert and William A. Rush have contributed much to the successful colonization of *Culex tarsalis*.

The isometric drawing of the mosquito cage was prepared by Mr. E. L. Cole, biological engineer of the Rocky Mountain Laboratory.

AN ADULT MOSQUITO SAMPLER

JOHN W. KLOCK AND W. L. BIDLINGMAYER [1]

It has long been realized that light traps (Mulhern, 1942)* used for sampling mosquito populations are subject to several undesirable limitations. One of these is the inclusion of large numbers of unwanted insects with each trap collection, thereby adding to the task of mosquito identification. Another handicap is that conventional light traps must be located near sources of electricity for power and light, which greatly restricts the area in which they can operate. An attempt to overcome some of these difficulties was made by Lindquist *et al.* (1945), who used mosquito biting or landing rates as an index to their population densities. Other workers have used various modifications of this technique to meet special situations. The umbrella-trap described here is a further attempt to improve upon these methods. Its use enables one person to collect all of the insects that would normally congregate around him in a definite volume of air during a given length of time. It can be operated during the night or day in almost any area accessible to an individual, and

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare, Savannah, Georgia.

* See also Mulhern, T. D., this issue of *Mosquito News*, page 130.—Ed. Note.

has the further advantage of trapping all of the insects which are attracted to him.

The trap consists of suitable netting rolled on a circular frame that is mounted on the top of a central pole (figure 1). After determining the proper location for sampling, the operator places the pole point on the ground and anchors it firmly by applying pressure with his foot to the stirrup (A) at the lower end of the pole. A piece of canvas or other suitable material is spread on the ground around the pole. The operator then stands on the canvas under the rolled-up netting and after a suitable exposure period releases the netting enclosing himself within it. A steel ring at the bottom of the netting causes it to fall rapidly and uniformly, and helps form a tight seal with the canvas on the ground. The specimens may then be collected at leisure with an aspirator, or when collecting large numbers they may be killed with a pyrethrum aerosol and quickly recovered from the canvas.

The trap can be made of metal or wood and any type of mosquito netting. The effective diameter of the frame is 4 feet. It is held 7½ feet above the surface of the ground by the center pole when the trap is in position ready for use. The top is formed by a four-spoked hoop, covered with screen or netting, with the upper end of the drop netting attached to the outside of the frame. This drop netting is rolled up and held in place by four cloth straps (B), one at the outer end of each spoke. One end of each strap is fastened permanently to the frame. The other is hung on the steel pins (C) behind which is a metal washer (D) connected to a handle (E) by a cord. When the handle is pulled down, the four washers are pulled off the pins carrying the straps with them, thus allowing the netting to fall to the ground.

When the sampler is to be moved, the cords are wrapped around the bolts (F), passed over the groove at the ends of the

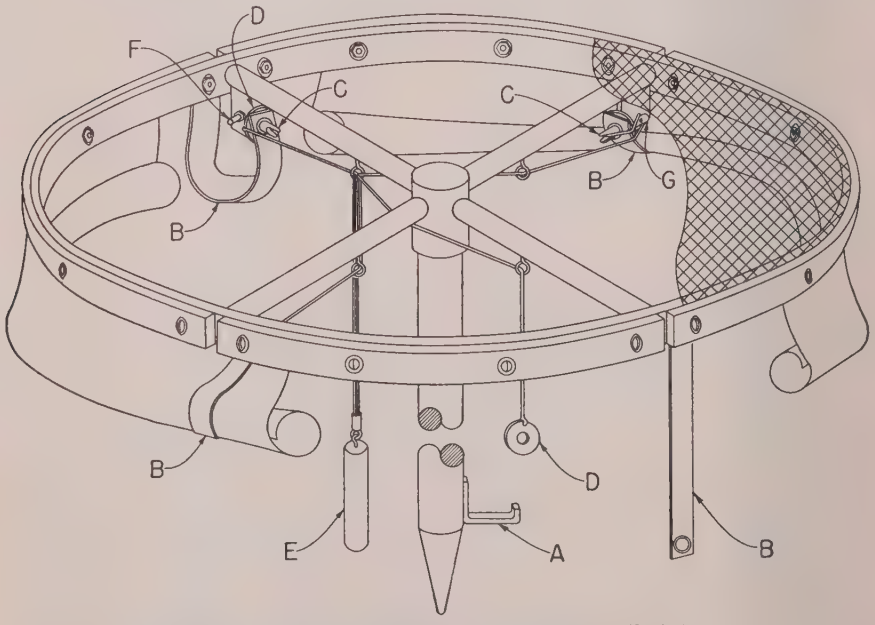

FIGURE 1 : A SCHEMATIC DRAWING OF AN ADULT MOSQUITO SAMPLER.

steel pins and hooked behind the jam cleats (G), thus securing the netting during transportation.

While this umbrella-trap was developed primarily for use in sampling adult mosquito populations, it could also be used advantageously in studies on other biting insects such as stable flies, deer flies, blackflies, and biting gnats.

Authors' Note: When this manuscript was sent to the Florida State Board of Health for comment, it was pointed out to us that Mr. J. A. Mulrennan and Mr. R. R. Sheppard had independently developed an essentially identical device over two years ago. Their device was recorded in their reports, but the description of it has never been published.

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SEASONAL SUCCESSION OF MOSQUITO SPECIES AND THE RELATIONSHIP EXISTING BETWEEN DISSOLVED MINERALS IN MOSQUITO-BREEDING WATERS AND SPECIES

CHARLES O. MASTERS

For several years prior to 1953, the author made a rather comprehensive study of the habits of the mosquitoes in Cuyahoga County, Ohio. One of the experiments conducted in 1952 was carried out in order to determine whether or not there would be a succession of species among the mosquito larvae found in a body of water throughout the breeding season, and also, if there might be a relationship existing between the amount of mineral matter dissolved in mosquito-breeding waters and the species found therein.

On June third, 1952, five large metal tanks, 6 feet long, 3 feet wide, and 1½ feet deep, were arranged side by side in a vacant lot and filled with tap water. Various quantities of water were passed through a bushel basket of horse manure and allowed to drain back into the tanks. As the minerals present in the manure came into solution, and passed into the tanks, the total amount of dissolved matter gradually increased. Measurements were made with a Barnstead Purity Meter in order to determine the grains per gallon, in terms of sodium chloride, of mineral matter present. The tap water contained eight grains per gallon as it was run into each of the five tanks. By the use of horse manure, this was increased in the tanks as follows: Tank Number One, 11 g/gal.; Tank Number Two, 14 g/gal.; Tank Number Three, 16 g/gal.; Tank Number Four, 24 g/gal.; Tank Number Five, 40 g/gal.

The color varied from a very light brown (610 millimicrons) to a dark brown. The difference in concentration became more apparent after testing with a Leitz Photometer. The percent transmittance was recorded as follows: Tank Number One, 94%T.; Tank Number Two, 90%T.; Tank Number Three, 83%T.; Tank Number Four, 72%T.; Tank Number Five, 72%T.

Nothing more was added to the tanks except manure water whenever a test with the Purity Meter indicated it was necessary. All of the tanks were fully exposed to sunlight but, because of their large surface area, the temperature never exceeded

82 degrees Fahrenheit. The pH of the water always remained above seven.

Regular collections of larvae were made by means of a net, 6 by 10 inches in size. A single sweep was made just below the surface of the water from end to end of the tank. This method was carried out throughout the summer. The catch was preserved in Carl's Solution (F.A.A.) and kept in a bottle until identifications could be made at a later date.

The population peaks of pupae usually followed the peaks of early instars by about ten days.

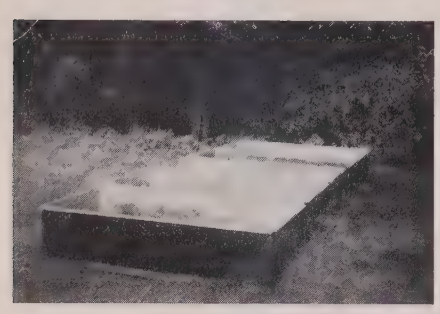


PLATE 1. Photograph of the five tanks as they were arranged in the vacant lot.

CONCLUSIONS

From the graph, it is obvious that there was a succession of species among the mosquito larvae. It would be of interest to repeat the experiment in a wooded area where there might be a greater variety of mosquitoes present.

At first there seemed to be no correlation between the number of mosquitoes actually "produced" by the tanks and the

RESULTS

	TANKS					
	1	2	3	4	5	
Number of Mosquito Species Collected:	3	3	5	5	5	
Early Instars:	701	447	574	1,450	2,628	
Percentage:	12	7	9	24	48	
Late Instars:	657	1,189	762	1,378	2,223	
Percentage:	10	19	12	22	37	
Total:	1,358	1,636	1,336	2,828	4,851	12,009
Percentage:	11	13	11	23	42	
Pupae Collected:	235	681	401	475	263	
Percentage:	11	33	19	25	12	
Number and Percentage by Species.						Total
Culex pipiens	566	1,114	463	1,218	2,013	5,374
Percentage:	86.30	93.80	60.77	88.41	90.59	
C. restuans	59	53	276	93	168	649
Percentage:	8.90	4.40	36.22	6.74	7.55	
Anopheles punctipennis	32	22	9	11	2	76
Percentage:	4.80	1.80	1.18	0.79	0.08	
Aedes triseriatus	0	0	13	8	28	49
Percentage:			1.70	0.58	1.25	
C. apicalis	0	0	0	48	0	48
Percentage:				3.48		
O. signifera	0	0	0	0	12	12
Percentage:					0.53	
Aedes cinereus	0	0	1	0	0	1
Percentage:			0.13			
Date of Greatest Production of Pupae:	6/24 8/15 8/19	8/12	6/24 7/28	6/24	6/24	
Daphnia Collected:	1,745	1,718	2,922	0	11	

amount of available salts present in the water, but that was so only because the author expected the population to be in direct proportion to the amount of dissolved mineral matter. Actually the number of larvae present in the tanks containing most of the mineral matter was greater but the number of adults produced was always less. In fact, the tank containing most of these salts produced only twelve percent of the adults produced by all of the tanks which was significantly no more than the number produced by the tank containing the least amount of mineral matter. Similarly, more daphnia were produced in the tanks containing the least amount of dissolved mineral matter.

The mortality rate among mosquito larvae seemed to be highest during the period between the third instar and the pupal stage.

Once more, using the quantity of mosquito pupae present as an index to the tanks' productivity rate, the greatest number of adults was produced during the third week of June. From that day on, the rate gradually declined in spite of the fact that manure was being regularly added to the tanks in order to maintain the proper salt concentration.

Since only seven species of mosquitoes were identified in the tanks, there was not much evidence as to whether or not there was any correlation between species and the amount of dissolved mineral matter present. Most of the species were distributed equally in the various tanks but *A. punctipennis* seemed to show a preference for the more dilute habitats whereas *O. signifera,* a common tree-hole species, was taken only in the most highly concentrated mineral waters.

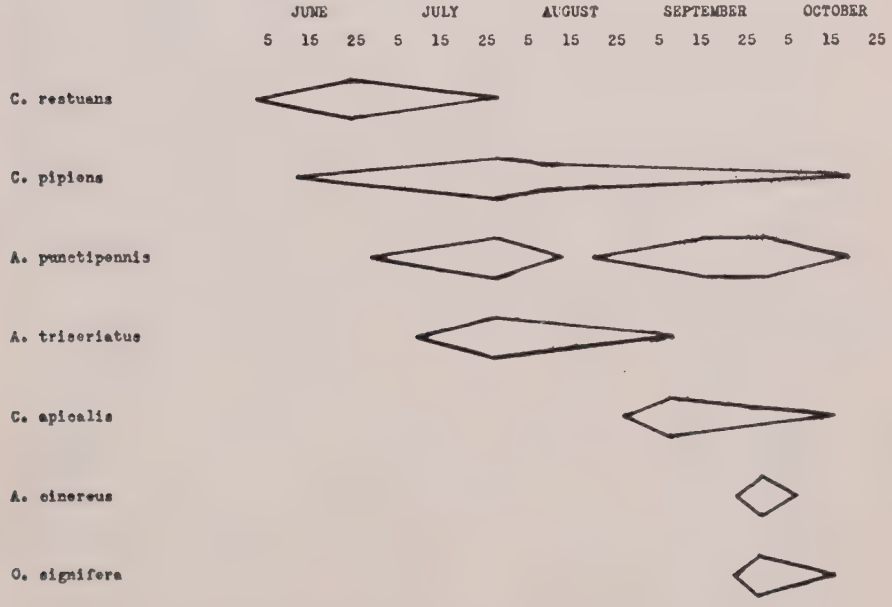


PLATE 2. Graph showing the succession of species during the mosquito season of 1952.

PICTORIAL KEYS TO THE MOSQUITOES OF MEDICAL IMPORTANCE III. MALAYA

KATHRYN M. SOMMERMAN AND RICHARD H. FOOTE

Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, United States Department of Agriculture

The accompanying keys continue a series being prepared under a transfer of funds from the Department of the Army to the Bureau of Entomology and Plant Quarantine, which are designed primarily to assist public-health workers in rapidly separating and identifying the mosquito species of primary medical importance (Mosquito News, vol. 13, no. 1, March 1953). The keys are so constructed that they separate the important species not only from each other but also from all other species known to occur in the area concerned. Suggestions and comments will be welcomed, particularly from persons having information on the faunas of the countries involved.

Although 48 species of *Anopheles* are known from Malaya, only 8 are especially important as vectors of malaria. *A. sundaicus* and *A. minimus minimus* are of great importance wherever they occur. The former is typically a brackish-water breeder and occurs along the entire coast, where it is responsible for the extensive endemic malaria present there. *A. minimus minimus* breeds throughout Malaya in slow-running, partly shaded streams and springs. *A. minimus flavirostris*, although an important vector in the Philippines, is extremely rare in Malaya. The larvae of *flavirostris* and typical *minimus* are virtually indistinguishable. *A. maculatus*, an extremely important vector, inhabits foothill regions near coastal areas and prefers sunlit breeding places, entering cleared areas to replace those species, such as *umbrosus*, which prefer shaded sites. The latter is also an important vector, but is restricted to jungle swamps and their immediate vicinity in the plains region. *A. letifer*, a close relative, is one of the most economically important vectors, breeding and transmitting malaria to a high degree in plantations in the flat coastal areas. *A. barbirostris* is not considered to be important in Malaya, except where it occurs in great numbers or serves as an accessory vector during an epidemic. Because of past confusion in identification of *sinensis* and *hyrcanus nigerrimus*, some doubt still exists as to their relative medical importance in Malaya. However, both have been found naturally infected there, and are thought to play a role in malaria transmission. Both species generally breed in open situations, such as rice fields, lakes, and the edges of slowly moving streams.

In addition to those mentioned above, the following species of *Anopheles* have been recorded from Malaya, or are suspected of being present in that country: *aconitus, aitkeni aitkeni, aitkeni bengalensis, aitkeni palmatus, albotaeniatus, annandalei annandalei, annularis, asiaticus, aurirostris, baezai, barbumbrosus, brevipalpus, brevirostris, gigas sumatrana, hunteri, hyrcanus williamsoni, insulaeflorum, karwari, kochi, letifer, leucosphyrus hackeri, leucosphyrus leucosphyrus, lindesayi cameronensis, minimus varuna, montanus, pallidus, philippinensis, ramsayi, roperi, schuffneri, separatus, similissimus, subpictus indefinitus, subpictus malayensis, subpictus subpictus, tessellatus, vagus, watsoni*, and *wellingtonianus*.

Of the approximately 175 nonanopheline mosquitoes known definitely to occur in Malaya, only *Aedes aegypti* and *albopictus* are the vectors of dengue fever, a common disease in Malaya. Both of these mosquitoes are urban, and they breed in all kinds of artificial containers near human habitations.

MOSQUITOES OF MEDICAL IMPORTANCE - MALAYA

FEMALES

[MALES HAVE BUSHY ANTENNAE ( ) AND DO NOT BITE]

IMPORTANT
A SPECIMEN MUST HAVE ALL CHARACTERS LISTED FOR THAT SPECIES

INSECT IDENT., BEPO, USDA UNDER FUNDS ALLOTTED BY SECRETARY OF ARMY AUGUST 1952

LONG PALPS ON *ANOPHELES*

PATTERN ON FEMUR & TIBIA

PATTERN ON PALP

ENTIRELY DARK

WING

NOT ENTIRELY DARK FROM BASE TO FORK ON VEIN 4

PATTERN ON FORE TARSUS

PALE BAND ABOUT AS LONG AS WIDE ON FIRST TWO OR MORE BASAL SEGMENTS

PATTERN ON HIND TIBIA

NO PALE BAND

= *ANOPHELES UMBROSUS*

ENTIRELY DARK

PROPLEURAL HAIRS ABSENT (SEE ENLARGED DRAWING FOR LOCATION)

= *ANOPHELES LETIFER*

VEIN 4 DARK EXCEPT FOR LIGHT SPOTS ON BRANCHES

SMALL FRINGE SPOT AT TIP OF VEIN 3

NOT BROAD

= *ANOPHELES BARBIROSTRIS*

4 NARROW WHITE BANDS

MIDDLE SPOT ON VEIN 6 AT LEAST AS LONG AS APICAL SPOT

PATTERN ON HIND TARSAL SEGMENTS 3,4 & 5

= *ANOPHELES HYRCANUS NIGERRIMUS*

PATTERN ON HIND TARSAL SEGMENTS 3,4 & 5

= *ANOPHELES SINENSIS*

2 BROAD AND 1 NARROW WHITE BANDS

PATTERN ON PROBOSCIS

ALL DARK, OR WHITE-TIPPED

SMALL LIGHT SPOT IN BASAL THIRD

= *ANOPHELES MINIMUS*

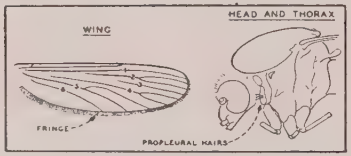
1 BROAD AND 2 NARROW WHITE BANDS

PATTERN ON HIND TARSUS

= *ANOPHELES SUNDAICUS*

2 BROAD AND 1 NARROW WHITE BANDS

= *ANOPHELES MACULATUS*



SHORT PALPS ON ALL OTHERS

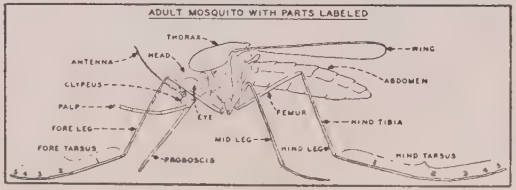
PATTERN ON THORAX

PATTERN ON HIND TIBIA

NO PALE BAND

= *AEDES AEGYPTI*

= *AEDES ALBOPICTUS*



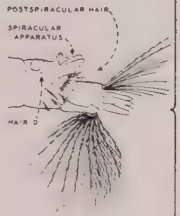
MOSQUITOES OF MEDICAL IMPORTANCE – MALAYA

FULL-GROWN LARVAE

IMPORTANT
A SPECIMEN MUST HAVE ALL CHARACTERS LISTED FOR THAT SPECIES

INSECT IDENT. BEPO, USDA UNDER FUNDS ALLOTTED BY SECRETARY OF ARMY AUGUST 1952

NO SIPHON ON *ANOPHELES*



LONG PLEURALS OF 3RD GROUP

BOTH BARE

PALMATE HAIRS ON 3RD & 4TH SEGMENTS
(SEE ENLARGED DRAWING)

FULLY DEVELOPED ON BOTH + OUTER CLYPEALS AT LEAST 27 BRANCHED

PROTHORACIC HAIR 1

8 TO 14 BRANCHED = *ANOPHELES BARBIROSTRIS*

BARE OR BRANCHED AT TIP + INNER SUTURAL HAIR 3 TO 18 BRANCHED = *ANOPHELES HYRCANUS NIGERRIMUS AND SINENSIS*
(BOTH IMPORTANT; LARVAE CANNOT BE SEPARATED)

UNDEVELOPED ON 3RD + SPIRACULAR APPARATUS (NOT) CLUB = *ANOPHELES UMBROSUS*

UNDEVELOPED ON BOTH + TIP OF ANTENNA HAIR WITH 1 OR 2 STOUT, HOOKED BRANCHES + HIND CLYPEALS SHORT AND 2 TO 4 BRANCHED + 3RD SEGMENT LATERAL HAIR 13 TO 20 BRANCHED AND HAIR 0 3 OR 4 BRANCHED = *ANOPHELES LETIFER*

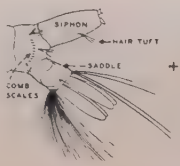
ONE HAIRED + INNER CLYPEALS BARE AND CLOSE TO OUTER CLYPEALS + ABDOMINAL PLATES BARE (NOT) = *ANOPHELES MINIMUS MINIMUS AND MINIMUS FLAVIROSTRIS*
(*FLAVIROSTRIS* NOT IMPORTANT; LARVAE CANNOT BE SEPARATED)

BOTH HAIRED

ANTENNAL HAIR ⅛ TO ⅓ DISTANCE FROM BASE + OUTER CLYPEALS (OR) (NOT) + PLEURALS OF 1ST GROUP (NOT) + LATERAL HAIRS ON 5TH & 6TH SEGMENTS 2 TO 6 BRANCHED = *ANOPHELES MACULATUS*

MIDWAY + HIND CLYPEALS PLACED FAR BACK OF INNER CLYPEALS (NOT) = *ANOPHELES SUNDAICUS AND SUBPICTUS*
(ONLY *SUNDAICUS* IMPORTANT; LARVAE CANNOT BE SEPARATED)

SIPHON ON ALL OTHERS



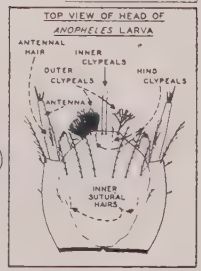
SIPHON: ONLY 1 TUFT PER SIDE; EVENLY SPACED; ABSENT

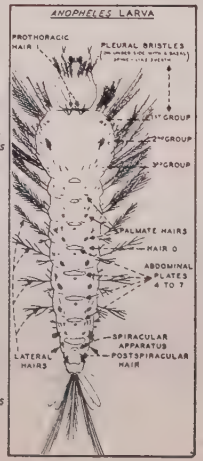
COMB SCALES IN ONE REGULAR ROW (NOT ON A PLATE)

ANTENNA: SMOOTH; NOT

COMB SCALES = *AEDES AEGYPTI*

SADDLE + BARE OF SPINES (NOT) = *AEDES ALBOPICTUS*





LIGHT TRAP STUDIES ON MOSQUITOES AND CULICOIDES IN WESTERN PUERTO RICO

IRVING FOX

School of Tropical Medicine, San Juan, P. R.

AND

JENARO MALDONADO CAPRILES

College of Agriculture and Mechanic Arts, Mayagüez, P. R.

New Jersey type light traps have been used extensively in Puerto Rico during the last decade, but they have been located mostly in the eastern half of the island (Pritchard and Pratt, 1944). In the project reported on here the light trap was situated at Mayagüez, an important city of the west coast, in a place which is about 100 meters from the sea in an area that includes many houses, sugar cane fields, mangrove swamps and low level ground subject to prolonged flooding by fresh water. From March 31, 1951 through March 28, 1952 in the course of 276 trap nights, 73,010 mosquitoes were collected. *Culex* males were all identified by the terminalia but *Culex* females were counted as "*Culex* undetermined"; the members of other genera were determined on the basis of external characters. In order of abundance the 23 species of mosquitoes encountered were as follows:

Uranotaenia lowii Theobald, 10,980 males and 38,322 females; *Culex* undetermined, 5,658 females; *Uranotaenia cooki* Root, 199 males and 4,255 females; *Culex nigripalpus* Theobald, 2,882 males; *Deinocerites cancer* Theobald, 376 males and 2,115 females; *Anopheles albimanus* Wiedemann, 134 males and 1,399 females; *Aedes taeniorhynchus* (Wiedemann), 182 males and 1,308 females; *Anopheles vestitipennis* Dyar and Knab, 205 males and 933 females; *Culex habilitator* Dyar and Knab, 852 males; *Culex atratus* Theobald, 837 males; *Psorophora confinnis* (Lynch Arribálzaga), 83 males and 680 females; *Culex quinquefasciatus* Say, 646 males; *Anopheles grabhamii* Theobald, 42 males and 405 females; *Uranotaenia sapphirina* (Osten Sacken), 80 males and 237 females; *Aedes tortilis* (Theobald), 50 males and 31 females; *Culex iolambdis* Dyar, 36 males; *Mansonia flaveola* (Coquillett), five males and 30 females; *Aedes mediovittatus* (Coquillett), 16 males and eight females; *Psorophora pygmaea* (Theobald), two males and seven females; *Culex bahamensis* Dyar and Knab, four males; *Culex opisthopus* Komp, four males; *Culex erraticus* (Dyar and Knab), four males; *Culex sardinerae* Fox, two males; *Aedes sollicitans* (Walker), one female.

The number of trap nights for each month was as follows: April, 26; May, 27; June, 20; July, 26; August, 20; September, 18; October, 33; November, 23; December, 18; January, 15; February, 25; and March, 25. Table 1 shows that *An. albimanus, Ae. taeniorhynchus, U. lowii* and undetermined *Culex* females and *C. nigripalpus* males were most abundant from May through September, which was the period of greatest precipitation. *D. cancer* and *An. vestitipennis* had a similar seasonal variation, but *U. cooki,* did not, being most numerous from November through March.

The trap yielded a total of 22,566 specimens of *Culicoides* distributed among eight species, as follows: *C. furens* (Poey), 16,826; *C. inamollae* Fox and Hoffman, 3,129; *C. pusillus* Lutz, 2,611; *C. foxi* Ortiz, 16; *C. loughnani jamaicensis* Edwards, 8; *C. hoffmani* Fox, 3; *C. phlebotomus* (Williston), 3; and *C. borinqueni* Fox and Hoffman, 1. Table 2 shows that the data do not permit a conclusion in regard to the seasonal variation of *furens,* except that abundance was not related to

TABLE 1. Monthly Average No. of Mosquitoes per Light Trap Night at Mayagüez, P. R. (*C. nigripalpus*, males, the others females) and the Rainfall in Inches.

Month	Rainfall	*albimanus*	*taeniorhynchus*	*lowii*	*Culex* Undet.	*nigripalpus*
April	3.63	1.3	6.2	42.5	5.5	2.3
May	5.77	3.0	17.3	174.0	35.0	24.0
June	4.54	6.4	10.2	52.2	15.6	6.0
July	14.59	12.3	15.9	463.0	40.5	20.6
August	7.51	18.4	1:2	485.0	32.1	38.6
September	13.94	13.5	0.2	264.0	22.1	16.0
October	6.80	4.5	0.0	79.8	13.8	6.5
November	7.63	0.7	0.1	69.1	17.0	2.9
December	3.29	0.6	0.1	14.7	16.5	5.1
January	3.78	0.2	0.1	4.0	22.0	1.1
February	0.31	0.4	1.0	3.1	10.0	1.0
March	1.53	1.4	0.2	13.4	18.3	2.0

TABLE 2. Monthly Average No. of *Culicoides* Specimens per Light Trap Night at Mayagüez, P. R. and the Rainfall in Inches.

Month	Rainfall	*furens*	*inamollae*	*pusillus*
April	3.63	246.5	4.0	1.7
May	5.77	125.9	3.0	0.4
June	4.54	15.8	11.4	0.2
July	14.59	33.1	16.3	3.0
August	7.51	41.3	10.6	4.4
September	13.94	46.7	15.7	7.2
October	6.80	53.2	11.8	7.7
November	7.63	53.5	19.6	26.4
December	3.29	55.0	23.1	25.2
January	3.78	97.9	24.3	57.9
February	0.31	10.9	4.6	2.6
March	1.53	5.2	2.5	1.5

rainfall. The months of greatest abundance of *pusillus* and *inamollae* were November, December and January, which is in accord with results of a previous study on the latter species at an interior situation in the island (Fox, 1952), and this is not due to the precipitation.

Acknowledgment.—Thanks are due the Weather Bureau, San Juan, P.R. for furnishing data not available in their bulletins (Climatological Data, West Indies and Caribbean, Vol. 31, 1951) and Dr. Alan Stone, U. S. National Museum, for checking some of the mosquito identifications.

Literature Cited

FOX, I. 1952. Light trap studies on *Culicoides* in Puerto Rico. *Jour. Econ. Ent.* 45(5): 888–889.

PRITCHARD, A. E. AND H. D. PRATT. 1944. I. A comparison of light trap and animal bait trap anopheline mosquito collections in Puerto Rico. II. A list of the mosquitoes of Puerto Rico. *Pub. Health Rep.* 59(7):221–233.

ASSOCIATION NEWS

SIDE LIGHTS OF THE DAYTONA BEACH MEETING. The official proceedings of the annual meeting will be duly reported to the membership elsewhere in MOSQUITO NEWS, but for those who could not be there the following items may be of interest.

The Association is indebted to Sam Minnich and his Committee on Arrangements for an outstanding display of hospitality. The work of a local committee usually involves a great deal of drudgery which sometimes is not fully appreciated. The meetings were held in the Ocean Room of the Sheraton Plaza (which hotel is also called Sheraton-Beach). A large picture window with a view of the Atlantic dominates this room.

The program lists the names of the thirty companies which had exhibits. These companies also contributed generously to two hospitality hours. The Florida Association and Florida Districts also were hosts. A fish fry on the beach was also a pleasant feature, and the hush-puppies will be long remembered. The dance on the evening of April 15 was well attended.

Harry Stage, Charlie Foulk, and Frank Steinrock conspired to raise money for the Good Neighbor Club at the Hospitality Hour preceding the banquet. Tickets were sold and a number was drawn from a hat. The winner, Mr. Jesse B. Leslie of Bergen County, N. J., very generously, though apparently involuntarily, donated his winning pot, so that the Good Neighbor Club reaped $103.00.

At the banquet, Toastmaster Sam Minnich was in fine form, but he introduced so many people that he didn't have time to tell many stories. Souvenirs were envelopes containing "A Positive Killer of All Types of Resistant Mosquitoes. . . . Anyone can use it. . . . Recommended by the President of the Florida Anti-Mosquito Association." Of course the envelopes contained fly-swatters.

In the lobby of the hotel, orange juice was supplied through the generosity of a Florida member. It was especially enjoyed by the large delegation of Californians.

Among the members whose pictures were featured on the front pages of the Daytona Beach newspapers were Helen Louise Trembley, Bill Komp, Rowland Dorer, Lester Smith, Ted Raley, Dr. Twinn and Dr. Bishopp.

THE FLORIDA ANTI-MOSQUITO ASSOCIATION at the Daytona Beach Meeting elected the following officers:

President—J. Melton Williams, Sarasota
President-elect—Dr. Maurice Provost, Fla. State Board of Health, Orlando
Vice-President—Edward M. Becton, Vero Beach
Secretary—John A. Mulrennan, Fla. State Board of Health, Jacksonville

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Two of our well-known members have died during the past few weeks, but MOSQUITO NEWS does not yet have full particulars.

Deed C. Thurman, Jr., Captain, U. S. Public Health Service, died April 18 in Chiengmai, Thailand, according to word received in Washington, D. C.

"D. C.," who for the past two years had been employed by the U. S. STEM (Scientific, Technical, Economic Mission) to Thailand, on a malaria control project, was planning to leave for home May 7, with his wife Ernestine, and their young daughter. On March 27, Ernestine, discussing the project in a personal letter, wrote:

"Plans are formulated to expand the program to include 5,000,000 people next year. Even with this great improvement in the health of the nation, there is yet much to be done. However, we are coming home with a feeling of gratification, knowing that we have contributed a bit to the betterment of a nation and for the security of the people of free countries."—H. L. T.

J. Lyell Clarke, Sanitary Engineer, The Desplaines Valley Mosquito Abatement District, died shortly after the meetings, on May 5, 1953.

The American Mosquito Control Association extends its sympathies to the families of these two valued members of our organization. We hope that a future number of MOSQUITO NEWS will carry more complete notices of appreciation of their contributions to mosquito control.

NEWS AND NOTES

IN A REPORT AT THE NEW JERSEY MOSQUITO EXTERMINATION ASSOCIATION MEETING in Atlantic City, Mr. Fred Reiley stated that 8,000 acres of typical marsh lands have been taken over by the United States Government as a wildlife refuge. For the past twenty years this area has bred mosquitoes and has required inspection and spraying in order to reduce mosquito annoyance there and in nearby residential areas. Since the Fish and Wildlife Service has taken over this land, the Service has refused to permit mosquito inspectors of Atlantic County to enter the area unless they are accompanied by Federal employees. Mosquito breeding in the refuge will have to be justified before mosquito control in the area is initiated. In order to help Mr. Reiley solve his problem, I suggested that he use *Gambusia* in all the water holes, but Mr. Reiley said he tried that but it did no good. All they did was to eat so many larvae that they turned their bellies up in the air and floated on their backs.—Tate Martin, General Foreman, Desplaines Valley Mosquito Abatemnet District.

AT THE ATLANTIC CITY MEETING there was considerable discussion by commissioners from the several New Jersey counties in regard to mosquito control needs in their respective counties. The people pressed them for better mosquito control, but this would require money which they don't have. However, the people and the commissioners could see that if they got rid of marshes by ditching them they would not have to go back each year to handle the situation, even though it would cost more money in the beginning. It seems that the commissioners were under pressure by the people who live near the marshes to drain them, and the commissioners all stressed draining and spraying as an essential part of their work.—Tate Martin.

THE MASSACHUSETTS RECLAMATION BOARD in March 1953 organized a new mosquito control project which encompasses a compact group of six communities located along the south shore of Massachusetts Bay. This organization, known as the South Shore Mosquito Control Project and directed by a local Board of Commissioners, will operate throughout an area of 81 square miles. Although the native population is only 157,461, during the height of the mosquito breeding season the native density of 1,828 per square mile is greatly increased by a heavy influx of summer visitors.

For its initial effort, the project has available approximately $530.00 per square mile for financing a complete mosquito control program. Several towns, bordering the perimeter of the control area, have exhibited an intense interest in the present endeavor. This aroused interest predicts a bright future and an almost immediate expansion of the South Shore Mosquito Control Project's area of operation.—B. I. Gerry

THE COUNTY COURT OF LANE COUNTY, OREGON, has authorized the expenditure of $5,000 emergency funds for mosquito control for the balance of the fiscal year 1952–53. Additional funds are being budgeted in order that a permanent mosquito control program may be conducted in Lane County.

The program of mosquito control will be under the jurisdiction of the Lane County Health Department with Mr. Milton H. Buehler as Director of the program. Mr. Buehler received his B.S. degree from the University of Arizona in 1941, majoring in Economic Zoology and Entomology. He has had several years experience in vector control as an insect and rodent control specialist in the U. S. Army and U. S. Public Health Service. Mr. Buehler is well known in Oregon where he served as Insect and Rodent Control Consultant for the Oregon State Board of Health for a period of two and one-half years. He is well qualified to take charge of the Lane County Mosquito Control Program.

The people in and around Eugene, the county seat, have become more and more conscious of mosquito annoyance. This, prompted by the encephalitis outbreak in California, crystallized the thinking of the county leaders to proceed with mosquito control.

The main species of mosquitoes with which the Lane County Court is concerned is *Culex tarsalis*. Breeding of this species is extensive in numerous log ponds and overflow areas. The program of mosquito control outlined is sound, and under the leadership of Mr. Buehler good results should be obtained.—A. W. Lindquist

AT THE NORTH AMERICAN WILDLIFE CONFERENCE in Washington, J. P. Linduska reported on March 11 that annual State and Federal expenditures for the restoration of waterfowl habitats exceed $8,500,000.

DR. BRYANT E. REES, Associate Professor of Entomology at Fresno State College and Technical Advisor to the Fresno Mosquito Abatement District has four namesakes. They are a crane fly, *Tipula reesi;* a mosquito, *Aedes reesi;* a rove beetle, *Staphylinus berberi,* and a son, Richard Bryant Rees. The insects were described respectively by C. P. Alexander, W. V. King, and R. E. Blackwelder. The name, *berberi,* was coined from Dr. Rees' initials.

THE FORTIETH ANNUAL MEETING OF THE NEW JERSEY MOSQUITO EXTERMINATION ASSOCIATION was held in Atlantic City, March 4–6, 1953. A feature of the meeting was a panel discussion on the topic, Mosquito Control on Public Lands.

The moderator was Dr. Louis A. Stearns of Delaware, and representatives of seven federal and state agencies participated. Dr. Bishopp presented his annual review, Mosquito Work throughout the World, prepared with the help of Harry Stage and Helen Sollers. The incoming president of the Association is Mr. Charles T. Foulk II, of Bloomfield.

IN PORTSMOUTH, VIRGINIA, larviciding catch basins and many road ditches is done by mosquito workers from the rear platform of a jeep. Due to traffic and parking conditions in the downtown area and on the streets adjacent to entrances to the Naval Shipyard, it has been necessary to work this section on a night shift from 11:00 p.m. to 7:00 a.m. Headlights of the approaching jeep would pick up such spots; but when the rear platform came opposite the place, there was no illumination to guide the spray operator. This led to faulty performance and sometimes a complete miss, which could be remedied only by backing up the jeep in the dark—an invitation to accident.

As a cure for this situation, an adjustable spotlight has been installed about half way down the back of the right front fender to shine back on the gutter or catch basin as best suited to the needs of the rear platform worker. It has seemed that an amber or fog lense is best suited for this purpose as it is easier on the eyes of the operator while he is spraying and does not reduce his vision afterward.—A. P. Page, Jr.

IN SOUTHEASTERN VIRGINIA, a new organization called the "Superintendents' Round Table" has recently been formed. Although the Virginia Mosquito Control Association holds a yearly meeting, it was decided that there was a need for a monthly meeting of the different commission superintendents so that they could discuss in an informal manner the problems of the various commissions.

They hold their meetings once per month at the various offices of the mosquito commissions. The first meeting was held at the office of Mr. R. E. Dorer, where Mr. Dorer was unanimously elected Chairman and Mr. A. P. Page, Secretary. At the second meeting it was discovered that a large amount could be saved by ordering each commission's insecticides in one group.

In the short time it has been organized, the Round Table has solved quite a few problems and brought the different commissions in closer unity.

DR. MARSHALL A. BARBER died on Jan. 15, 1953 at the age of 84. His distinguished career as a malariologist with the International Health Division of the Rockefeller Foundation, with the U. S. Army and with the Public Health Service led him into many phases of malaria control work throughout the world.

HERMAN L. FELLTON, for the past seven years Orkin Exterminating Co. vice-president in charge of technical operations and also vice-president of the Orkin Institute of Industrial Sanitation, is no longer with that organization and has gone into business for himself as a sanitary engineer and entomological consultant. His office is located at 15 Peachtree Place N.W., Atlanta, Ga. He will be available for consultation on all aspects of insect and rodent control and related matters.

Prior to joining Orkin, Mr. Fellton served for 5 years as a commissioned officer in the U. S. Public Health Service. He was one of the original staff of the Malaria Control in War Areas organization. Before that he was in charge of insect and rodent control activities at the New York World's Fair, particularly mosquito and midge (chironomid) control. He has been active in insect control work since 1934.

Mr. Fellton was one of the founding members of the Eastern Association of Mosquito Control Workers, which has since become the American Mosquito Control Association. He was a member of the Executive Committee from 1944 to 1946 and also served on the Publications Committee.

THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION held its twenty-first annual conference in Sacramento, Feb. 11–13, 1953. Considerable emphasis was given to problems relating to agriculture and mosquito control. Among other subjects discussed were water conservation programs, encephalitis, the measurement of mosquito populations, and effectiveness of some of the newer insecticides.

DR. JOSEPH HILL WHITE, retired Assistant Surgeon General of the U. S. Public Health Service died in Washington on Feb. 28, 1953. According to the Washington Post he is credited with the first successful control of a yellow fever outbreak in the United States by controlling mosquitoes at the Hampton, Virginia, Soldiers' Home in 1899. His work preceded that of Dr. Walter Reed with whom he was later associated for many years.

MR. NELSON H. RECTOR, who was a member of the A.M.C.A. for several years, retired from the U. S. Public Health Service in December 1952. Mr. Rector served in malaria control work for 31 years with the Rockefeller Foundation, Alabama and Mississippi State Boards of Health, and the P.H.S. He played an important part in the organization and development of the Malaria Control in War Areas program. Mr. Rector graduated in civil engineering from The Johns Hopkins University.

DR. L. L. WILLIAMS, JR., an honorary member of the A.M.C.A. recently retired from active duty with the Public Health Service. His many contributions in the field of malaria and mosquito control are well known. He had been chief of the Division of International Health, P.H.S., since 1948.

DR. MARTIN D. YOUNG recently received a Rockefeller Public Service Award. This grant

will enable him to have a "sabbatical leave," and he plans to visit laboratories and schools in England, France, Italy, Turkey, Egypt, Israel, India, Pakistan, the Philippines, and Australia.

LCDR JOHN M. HIRST, who is now stationed in Alameda, California, visited naval installations at Port Lyautey and Tripoli in December. He is editor of the *Ther-Mal Air-O-Sol* at the Naval Air Station. This news sheet dispenses "more hot air from the land of the sun." In March LCDR Hirst accompanied 2200 flies on a trip to Honolulu aboard the Philippine Mars. The purpose of this jaunt was to test the efficiency of a new system for releasing insecticides in the plane. The aerosol is released automatically when the pilot pushes a button. The treatment of the caged flies was successful.

THE EIGHTEENTH ANNUAL REPORT OF THE DADE COUNTY (FLA.) ANTI-MOSQUITO DISTRICT emphasizes the many problems involved in water management in that area. A ten-year plan known as the Army Engineers Flood Control and Water Conservation Project has been put into effect. It calls for many miles of levees and canals and other works which will result in the impoundment of vast acreages. Aside from organized efforts, private land owners are attempting to control water and salt infiltration by building dikes, dams, ditches, tide-gates. The purpose is to keep the land flooded in the summer to prevent salt contamination and weed growth and to destroy certain crop insects. This standing water is, of course, a source of large numbers of mosquitoes. The removal of excess water prior to and during the growing season also constitutes a mosquito-control problem. The effect of so much water storage in some of the larger Conservation Districts cannot be predicted, but it is possible that vegetation will flourish and that *Mansonia* mosquitoes will have favorable conditions.

In salt marshes it is planned to emphasize ground spraying rather than airplane larviciding. To supplement hand spraying the power sprayer must be mounted on a tractor that will not bog down. An Oliver tractor, OC-3 model, was purchased. The frame has been elevated to give a ground clearance of 35 inches. Width from center to center of tracks has been increased to 72 inches. The track has been lengthened and there is less ground pressure per square inch due to two ⅜"x 4"x 30" wood extensions bolted to the track shoes. The tractor is equipped with a 400-pound pressure sprayer capable of delivering 7 gallons per minute. It can also be adapted for ditch maintenance work.

Space spraying with Buffalo turbines was continued in 1952. Good results were obtained by applying 2½ per cent DDT emulsion at the rate of one gallon per acre. Around 55,000 acres were treated by airplane with 5 per cent DDT in fuel oil at the rate of 2 quarts per acre.

THE DESPLAINES VALLEY (ILL.) MOSQUITO ABATEMENT DISTRICT is now in its twenty-sixth year of operation. The report for 1952 states that after being used for seven years, DDT and kindred chemicals have lost little of their lethal effect. The cost of mosquito control per capita is about 42 cents. Five routine foggings were made in heavily populated areas during the season. Truck speed was 3 m.p.h., and 8 per cent DDT oil solution was distributed at the rate of 0.123 lbs. of DDT per acre. The four machines averaged 141 gallons of material and 725 acres per night. Treatment of 29,505 catch basins was made with 25 per cent DDT in E-407 at the rate of about one-half pint per basin. A single application appeared to be adequate. Eighteen light traps were operated and collections reached a peak on August 1 when 3873 females were trapped. Over 97 per cent of these mosquitoes were *Aedes vexans*.

THE 1952 REPORT OF THE UNION COUNTY (N. J.) MOSQUITO EXTERMINATION COMMISSION marks the fortieth anniversary of control work in the county. Over thirty photographs are used to record work that has been done. Some of the large areas that were prolific sources of mosquitoes in 1912 are still troublesome. The North Elizabeth meadows which were diked and tide-gated in 1914–15 have dried out and sunk from three to four feet. This area is now covered with fresh water, heavily contaminated with sewage and industrial wastes. *Culex pipiens* moved in after the salt marsh mosquitoes moved out. At the present time drainage maintenance accounts for about 65 per cent of the man hours of labor, and the other 35 per cent is used in applying insecticides. There is a picture of eight employees who have worked for the commission 20 years or more.

AMCA PRESIDENT Dr. F. C. Bishopp, was given an Award for Distinguished Service by the United States Department of Agriculture, on May 19, 1953. Ezra Taft Benson, Secretary of Agriculture, in presenting a medal and scroll, made the following statement: Dr. Fred C. Bishopp, Assistant Chief of the Bureau of Entomology and Plant Quarantine, in charge of research, is a noted authority on medical and veterinary entomology. During World War II, he activated and coordinated research on disease-carrying mosquitoes, lice, and flies, and was awarded certificates by the Army and Navy, and received from Great Britain, His Majesty's Medal for Service in the Cause of Freedom. He is being cited today for his work in organizing, conducting, and directing research which has resulted in the development of effective methods of controlling plant pests, thereby contributing to the welfare of all mankind.

EDITORIAL

The editor hopes that our President, Doctor Bishopp, will not object to our using the editorial section of this issue to call attention to the following release from the U. S. Department of Agriculture. Doctor Bishopp's contributions of thought, time, and effort to the AMCA have been unique and outstanding. His participation in the annual meetings of the AMCA, and of the various State Mosquito Control Associations has become a tradition—one that we trust is so strong that the diversion of his official energies to another field cannot change it.

The AMCA is honored that during the last year of his official duties in the U. S. Department of Agriculture Doctor Bishopp is our President; we hope that he will retain as one of his pleasantest feelings of this year the knowledge that our entire membership has for him the most cordial affection and the most profound respect.

Doctor F. C. Bishopp to Coordinate Research on Pink Bollworm.

Dr. F. C. Bishopp, since 1904 associated with the U. S. Department of Agriculture's Bureau of Entomology and Plant Quarantine, will leave his present position as assistant bureau chief on June 30. He has accepted a position with the Oscar Johnston Cotton Foundation as coordinator of all Federal, State, and industry-sponsored research concerned with the control of this nation's most threatening cotton insect, the pink bollworm. He will headquarter at Brownsville, Texas.

Dr. Bishopp, who reaches automatic Federal retirement age within a few months, is looked upon by Federal and State agencies, as well as by the Foundation, as the outstanding choice of scientist and administrator to guide the development of this expanding effort against the pink bollworm. As coordinator, he will evaluate and recommend procedures of research to the organizations concerned with this problem designed to explore exhaustively all chemical, biological, and cultural methods of control of this pest. . . .

. . . Widely known for his research work with cotton insects and for his ability as a research administrator, since 1941, Dr. Bishopp has been the Bureau's assistant chief in charge of research. . . .

Dr. Bishopp recently received the Department of Agriculture's Distinguished Service Award for leadership in research that has materially contributed to the development of effective methods of controlling disease-carrying and crop-destroying pests.

During World War II, Dr. Bishopp was instrumental in guiding the research that led to the development of DDT and other materials which were widely and successfully used to protect service men and others the world over from malaria and yellow fever mosquitoes, typhus-carrying lice and mites, plague-carrying fleas, and other pests capable of transmitting human diseases. For this work he was awarded certificates by the Army and the Navy. Great Britain presented him with His Majesty's Medal for Service in the Cause of Freedom.

Dr. Bishopp, a native of Virginia Dale, Colo., has B.S. and M.S. degrees from Colorado A. and M. College and a Ph.D. from Ohio State University. He is a fellow of the Entomological Society of America (Vice-President 1932); was president of the Association of Economic Entomologists in 1937; president of the American Society of Parasitologists in 1938; president of the Washington Entomological Society in 1932; president of the American Mosquito Control Association in 1953, and a member of the American Society of Tropical Medicine and Hygiene, American Academy of Tropical Medicine, and Washington Academy of Science. He and Mrs. Bishopp reside at 8014 Piney Branch Road, Silver Spring, Md.

REVIEWS AND ABSTRACTS

EXPERT COMMITTEE ON INSECTICIDES, FOURTH REPORT, WORLD HEALTH ORGANIZATION. WHO Tech Rep't Series No. 54. Geneva, December 1952. $0.65.

This report sets forth specifications for certain common insecticides and their formulations. DDT, BHC, methoxychlor, chlordane and dieldrin are described as technical, water-dispersible and emulsion concentrates. Aerosols are defined and new aerosol formulations are given. Protective measures for the prevention of insecticide deterioration are presented. Particle size and shape in relation to biological efficacy are discussed. Diluents, solvents and emulsifiers are recommended. The report is concluded with several suggestions for sampling, testing aerosols and solvent-pressurized dispensers, aerosol test methods for flying insects and a chart of weights and measures. The contents of this report are practical, workable and complete. The data are unique in that they can be applied to insecticides on an international basis.

Although the report is prefaced with the statement that its contents do not necessarily represent the decisions or the stated policy of the World Health Organization, we were impressed by the character and the international recognition of the committee members which is reflected by every part of the report.

The members of the committee are Dr. R. A. E. Galley, Office of the Lord President of the Council, London, United Kingdom of Great Britain and Northern Ireland, chairman; Dr. H. L. Haller, assistant chief, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture, Washington, D. C., U. S. A., vice-chairman; Dr. H. Mazzari, Chief, Chemical Laboratory, Division of Malariology, Ministry of Health and Social Welfare, Maracay, Venezuela; Dr. Rajindar Pal, Assistant Director, Malaria Institute of India, New Delhi, India; and, Dr. J. Treboux, Laboratoire de Recherches, J. R. Geigy, S. A., Basle, Switzerland. Dr. F. P. Coyne, Pest Control Development and Technical Services, Imperial Chemical Industries, Ltd., Randle, Runcorn, Cheshire, United Kingdom of Great Britain and Northern Ireland is reported present as an observer. Mr. J. W. Wright of the Malaria Section WHO served as secretary.

Buyer-seller agreement on insecticides during procurement dealings is stressed as necessary for efficiency and satisfaction. The committee sets forth certain definitions, for example:

	Particle size
Coarse spray	400 microns and above
Fine spray	100–400 microns
Mists	50–100 microns
Aerosols	0.1–50 microns

The definitions are not exactly as some of us have been using but are worth much toward uniformity of understanding.

An excellent discussion concerning the use of aerosols on board aircraft is given by the committee. Among their important observations their report states that

1. Size of particles: (a) not more than 20% by weight of the aerosol shall consist of particles of diameter greater than 30 microns; (b) not more than 1% by weight of the aerosol shall consist of particles of diameter greater than 50 microns.
2. The valve shall not dribble before, during or after release of the aerosol.

In aircraft, for quarantine purposes, the ventilation system of the aircraft must be stopped and all openings to the outside kept closed during the time the insecticide is being released and for a period of at least 5 minutes, and preferably 10 minutes, thereafter. The insecticide solution must be dispersed at a rate of not less than 10g per 28 cubic meters (1,000 cu. ft.) of enclosed space in the aircraft, and must be released evenly throughout all compartments accessible from inside the aircraft.

Those who will find this report valuable will be interested in the recommendations of this Expert Committee. From their recommendations it is interesting to note the paucity of certain data most necessary to good formulating, accurate testing and biological efficiency.—John M. Hirst, LCDR MSC USN, Alameda, California.

(The Editor of Reviews and Abstracts calls attention to the fact that in the United States, World Health Organization publications may be obtained from the Columbia University Press, International Documents Service, 2960 Broadway, New York 27, N. Y., and in Canada from The Ryerson Press, 299 Queen Street West, Toronto, Ontario.

The names and addresses of agents in other countries may be obtained from the Editor of Reviews and Abstracts, or orders may be sent to the World Health Organization, Sales Section, Palais des Nations, Geneva, Switzerland.)

INSECT PHYSIOLOGY, Kenneth D. Roeder (Editor), New York, John Wiley & Sons, Inc., 1100 pp., 1953. This is the first comprehensive book on *Insect Physiology* to be published in this country. It is the result of a group effort by fifteen authors, led by the editor, to "summarize and evaluate the major trends in experimental research on insects." The discussion in the text relates to the following areas: integument and cuticle, respiration and metabolism, blood and circulation, the alimentary system, nutrition, excretion, neural activity and the nervous system, sensory reception, flight, behavior and social activities, embryonic and postembryonic development, regeneration, hormones in molting and metamorphosis. Anatomical details are included only as would seem to

an author necessary to elucidate function. The text is supported by 56 tables and 237 figures. There are 59 pages of index and about 107 pages of references to literature. With each reference are numbers indicating the text pages on which the citations are made.

Those who have contributed to the thirty-two sections or chapters of this book are: Raimon L. Beard, Dietrich Bodenstein, John B. Buck, Leigh E. Chadwick, Max F. Day, V. G. Dethier, George A. Edwards, Darcy Gilmour, Sam C. Munson, Robert L. Patton, A. Glenn Richards, Kenneth D. Roeder, Theodore C. Schneirla, William Trager, and Douglas F. Waterhouse.

The preface points out that this volume covers the literature up to but, in general, not later than 1951 and that much published work has not been included in the discussions because of limited space; hence, the sections are intended as critical rather than complete reviews. Information on mode of action of enzyme inhibitors, drugs, and other chemical agents has been included to provide a closer link between physiology, biochemistry, and entomology. The editor, in this preface, also emphasizes that insect physiology is not an isolated area of knowledge, that the insect physiologist is also a comparative physiologist, and that the physiologist's viewpoint has much to contribute to problems of insect control. Finally, the hope is expressed that this book may interest both undergraduate and graduate students of physiology, as well as other physiologists, insect morphologists, systematists, and applied entomologists.

It is not possible to review in a short space, in detail and critically, a book of this size and complexity. It is evident that this volume is intended more as a reference book, more as a survey of the field, than as a classroom textbook. An insect physiology textbook really suitable for classroom purposes has not yet come to the reviewer's attention; yet it would seem that this volume might be more suitable for this purpose than any book the reviewer has yet seen.

In a volume of this kind made up of contributions from different authors, some difference in quality and quantity of the sections is to be expected. Undoubtedly different readers will find various sections of more interest to themselves than others and may not believe that some portions of the book cover a particular area as critically or as completely as they would wish. Dr. Roeder, however, assisted by his collaborators, seems to have accomplished much in coordinating the various subject matter areas and in molding them into an interesting and useful volume. The reviewer feels that this first attempt on the part of a group of investigators in this field is a good one and that this volume represents a significant step forward in the field of insect physiology in this country.

A further contribution that undoubtedly would be of great assistance would be a smaller and simpler, and less expensive, classroom textbook suitable for courses in insect physiology currently being offered in entomology or other departments in colleges and universities in this country, often by teachers who are not primarily physiologists, to students, many of whom are likely to enter entomological areas other than insect physiology. Such a simplified text, together with the present volume for more detailed references, would make a combination extremely useful to many teachers. Perhaps some day one of the contributors to the book reviewed here will see fit to undertake such a task.

This book on *Insect Physiology* is recommended to all who are interested in the various aspects of this developing field.—J. Franklin Yeager, National Institutes of Health, Bethesda 14, Maryland.

BIOLOGIE D'ANOPHELES GAMBIAE. RECHERCHES EN AFRIQUE-OCCIDENTALE FRANCAISE. By M. H. Holstein. World Health Organ. Monogr. Ser. 9, 176 pp., 388 refs. French. English Summary, $2.00. 1952. The author condenses into an excellent book not only the previous studies conducted by other workers on *Anopheles gambiae* Giles but also his own work in French West Africa. He covers the distribution of this species in the Ethiopian region and French territories, seasonal variation, climatological information, and keys to fourth instar larvae, male and female adults of French West Africa, and morphological study of each stage. Two extensive chapters are devoted to the biology of the early stages and adults.

As the former classification of breeding places proved unsatisfactory, the author has suggested a division into two large categories—inorganic and organic breeding places according to the fauna and anopheline associations. The shortest life cycle was found in breeding places where temperatures were high and the content of the organic matter was less than 1.25 mg., viz. residual rain pools during a rainy season.

Holstein found that under laboratory and field conditions female *A. gambiae* are able to survive the long dry season in the Sudan by aestivating. Dark corners of native huts, destroyed huts, crevices in rocks, and tree holes are among the places of aestivation listed. In the laboratory females were found to aestivate up to 156 days. Females become active when the relative humidity is kept above 80 percent.

A. gambiae is responsible for epidemic outbreaks or high endemicity of malaria within certain limited zones while *A. funestus* was found to cause the average endemic state of the disease.

The author, after studying chiefly the geographical variations of *A. gambiae melas* along the coast of French West Africa, gives an account of his work on the differentiation between the zoophilic and anthropophilic forms of *A. gambiae*. —Helen Sollers, U. S. Dept. Agriculture, Washington, D. C.

CONVERSION TABLES AND EQUIVALENTS FOR USE IN WORK RELATING TO INSECT CONTROL. R. H. Nelson. U. S. Dept. Agric. Bureau of Entomology and Plant Quarantine Circular E-517, revised.

21 pp. May 1952. The opening paragraphs and the table of contents of this publication speak for themselves.

"In the literature on economic entomology the weights and measures used in expressing concentrations and dosages of insecticides may be in one or more of three systems—the United States, the imperial (British), and the metric. Since information on the relationships and equivalents in these systems is not always readily available to entomologists in the field, it has been assembled here for their benefit. The data on equivalents are taken principally from publications of the National Bureau of Standards and the International Critical Tables. A comparative discussion of United States and British units by Bearce and a paper by Irwin were sources of valuable information.

"Tables of equivalents for use in diluting insecticides, methods of calculating concentrations on the basis of active ingredients, and certain other miscellaneous information useful to entomologists working with insecticides have also been included.

"The measurement equivalents are carried out to sufficient decimal places to furnish accurate figures for precise laboratory work. They can be rounded out at the decimal place best suited for the equipment of the individual worker. The concentration equivalents have been carried out one to three places. In recommendations for practical use it is suggested that values be given as whole numbers or in steps of one-half wherever possible without gross error."

The major headings in the Contents are: Mass; Capacity—liquid measure; Capacity—dry measure; Linear, square and cubic measure; Diluting insecticidal chemicals; Dosage equivalents and relationships; Fumigation; Miscellaneous; Literature cited.

Examples are given of some of the problems which might arise in the field; and these are solved in the text by means of simple formulae and arithmetic and the use of tables.—H. L. T.

EXPERIMENTAL USE OF A HELICOPTER AS A LARVICIDAL AIRCRAFT FOR THE CONTROL OF *Anopheles quadrimaculatus*. By W. F. Wilson, E. A. Philen, and C. W. Kruse. Proc. New Jersey Mosquito Exterm. Assoc. 1952. pp. 117–131. Studies were made to compare the Bell helicopter, Model 47-D, with a fixed-wing Vultee BT-13 plane as a larvicidal aircraft for the dispersal of sprays for the control of *A. quadrimaculatus*. The two types of aircraft produced similar spray spectra and similar effective swath widths. Certain large areas were treated in approximately the same time by the Vultee flying at 120 miles per hour and the helicopter flying at 60 miles per hour; this was due to the difference in turn time involved (43 sec., Vultee, and 17 sec. helicopter). Reservoir treatment-time studies showed that the total time involved for each type of ship was within such limits that completion of a daily larvicidal operation could be easily accomplished before atmospheric conditions became unfavorable. General observations indicated that spray particles settled at similar rates with the Vultee flying at 120 miles per hour and the helicopter flying at 40 and 60 miles per hour, but below 40 miles per hour the downwash of the helicopter appeared greater, and at hovering, this factor was difficult to measure due to the very high velocities of the spray particles. All factors considered, spray speeds of 40 to 60 miles per hour were considered more favorable for routine treatment with the helicopter than slower speeds. The helicopter, when in good mechanical condition and flown by a skilled pilot, can be expected to handle the routine larvicidal load of a single reservoir as effectively as the fixed-wing Vultee. The investigation and field demonstration led to the general conclusion that the helicopter equaled or in some instances, because of superior maneuverability, slightly exceeded the performance of the Vultee as a larvicidal aircraft for the control of *A. quadrimaculatus*.—Authors' summary.

INTERIM REPORT OF THE DISTRIBUTION OF THE MOSQUITOES OBTAINED IN THE NORTHERN INSECT SURVEY. T. N. Freeman, 1952, Environmental Protection Technical Report No. 1, Defence Research Board, Ottawa, 45 pp. This is a preliminary report of the distribution of the mosquitoes of northern Canada. It is based on those species that have been reared by the Northern Insect Survey parties from 1947 to 1950 inclusive. Information was obtained on 43 species at 29 Arctic and Subarctic localities. Only four species occur in the tundra regions, two of which, *Aedes nigripes* (Zett.) and *Aedes pullatus* (Coq.), occupy similar habitats in northern Europe and Asia. *Chaoborus, Eucorethra,* and *Mochlonyx* are included in the 43 species. Distributional maps are given for each species.—H. H. Stage.

SINTESE DAS ATIVIDADES DO SERVIÇO NACIONAL DE MALÁRIA DO BRASIL NO DECÊNIO 1942–1951—CAMPANHA CONTRA A MALÁRIA, A DOENÇA DE CHAGAS E A FILARIOSE. By F. M. De Bustamante. Rev. Brasileira de Malariologia e Doenças Tropicais 4(3):231–244. Rio de Janeiro 1952. The author has written an abbreviated report of the activities of the National Service of Malaria between 1942 and 1951. Before 1950, the combat against malaria constituted the main objective of the Service, but from then on a program of control of American trypanosomiasis (Chagas' disease) was started, to comply with an executive order issued in December of that year. In August 1951, the Minister of Health directed the N.S.M. to take up the task of studying the incidence of bancroftiasis in Brazil and to carry out adequate control measures wherever indicated by already known or future findings. The work against bancroftiasis was begun in that same year with the realization of two surveys. Before the advent of DDT, the fight against malaria was mainly based on the classical methods of

antilarval measures (hydraulic sanitation work and application of larvicides) in the area where the disease is transmitted by species of the subgenus *Nyssorhynchus (darlingi, tarsimaculatus* and *albitarsis)* and by the picking up of bromeliaceae and the destruction of woods infested by these epiphytes in the districts where the vectors are of the subgenus *Kerteszia (cruzii* and *bellator).*

At present, the malaria control is based essentially in the spraying of DDT inside the dwellings, this method having been applied, during the year 1950 in 2,603,023 houses distributed in about 50 thousand localities of almost 900 counties, with an approximate aggregate population of 25 million. The paper is illustrated with data demonstrating the excellence of the results obtained through the use of DDT. The reduction of the incidence of the disease in the sprayed areas is in general very good (90 per cent and up).

The campaign against Chagas' disease was begun in the second semester of 1950. . . . The first stage of the campaign against bancroftiasis includes epidemiological surveys, already begun in several cities of the country, and the combat against this disease in the city of Belem, state of Para consisting mainly in introdomiciliary application of BHC. 43,000 houses of the city will be sprayed, quarterly, with an average dose of 300 milligrams of the gamma isomer per square meter in each application. The known carriers of microfilariae will be treated with Hetrazan, aiming at the reduction of the source of contamination of *Culex fatigans,* by far the principal mosquito vector of the disease.—Author's English summary.

STUDIES ON THE BIONOMICS OF *Anopheles aquasalis* CURRY, 1932. Senior-White, R. A. Indian J. Malariol. 5:294–403; 5:465–512; 6:29–72; 1951–2. This is one of the most extensive accounts of a mosquito species which has appeared for many years. Although it relates to a single species or species group and mainly to Trinidad, it contains much information and comment of wider import.

The paper is divided into three parts and nine sections as follows. Section I: Introductory, 6 pages of review. Section II: Races in *A. aquasalis;* 8 pages, in which it is suggested that residual DDT applications in houses have led to the evolution of a primarily zoophilic race, by selectively killing females with low maxillary index. Section III: one page on Distribution in Trinidad. Section IV: General breeding ecology, 3 pages covering egg production and larvel requirements. Section V: Duration of a complete generation, 6 pages; the duration is estimated from laboratory observations, and periodical sampling of larval populations. Section VI: Detailed breeding area studies, 20 pages on typical plant associations, predators, and other ecological factors. These sections, with 55 references, 38 tables, and a chart make up part I. Part II consists of Section VII: Adult bionomics, 31 pages, with 24 references, 10 tables and 2 charts, and deals with such matters as daytime resting places; predators and mortality during the gonotrophic cycle; activities in relation to microclimate and time of day; swarming, mating, and flight range; and seasonal density fluctuations. Part III consists of the last two sections, 23 references, and 7 tables. Section VIII: Adult feeding habits, 18 pages, gives the results of precipitin tests on blood fed females and describes experiments on blood preferences and on multiple feeding in one gonotrophic cycle. It also includes some of the very few published observations on flower feeding by *Anopheles spp.* Section IX deals directly with the transmission of malaria. In seven pages, the previous work on this subject is discussed, some data on the incidence of mosquito infections in various stages are given, and the densities required for transmission in various circumstances are calculated.

The author concludes that an extremely high population density of this species is necessary for malaria transmission, but that such a density does exist. It is suggested that an increase in the cattle population would have the double advantage of attracting blood-hungry females away from man and of reducing the vegetation which provides resting sites for females after feeding. A strong plea for more dissections to determine the oöcyst and especially the sporozoite rate in this and other neotropical species of *Anopheles* is advanced.

Some proof reading errors, difficult to avoid when an author is so widely separated from his publisher, are corrected in errata sheets; the change in Table XI however should not have been made. In places the results could have been more concisely expressed, nevertheless, this is a most valuable contribution and represents a tremendous amount of field and laboratory work.—B. Hocking, Department of Entomology, University of Alberta.

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